PROFESSIONAL NETWORKS AND PRACTICE CHANGE IN ENVIRONMENTAL EDUCATION

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PROFESSIONAL NETWORKS AND PRACTICE CHANGE IN ENVIRONMENTAL EDUCATION

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Professional development programs create communities of practice for environmental educators to exchange ideas and practice with each other through face-to-face and online activities. It is particularly important to understand how educators form networks through such communities, and how these networks impact their environmental education practice. Using multiple conceptual lenses -- including communities of practice, network formation, practice theory, professional development, and environmental education -- I examined the relationship between professional networks and practice change in environmental education. The professional development programs that are the focus of this study, including a state consortium that brought together environmental education and youth development professionals, an online learning community that explored urban environmental education, and a fellowship program focused on climate change education, are part of the North American environmental education professional development training program, EECapacity.

First, I explore environmental educators' communities of practice from a social network perspective by addressing the question: What were the characteristics of networks and the processes by which professional networks emerged in three environmental education professional development communities? I conducted surveys and social network analysis to examine educators' networks before and after the professional development programs. The results showed that educators had more network ties among each other after the programs than before the programs across all three groups. Also participating in face-to-face meetings and

online interactions increased the likelihood of educators' forming professional networks.

Next, I applied practice theory to explore the research question: How did environmental educators change their practice through participating in professional development communities? I conducted surveys and interviews to investigate educators' practice change as measured by elements of practice including goals, audiences, settings, activities, resources and ideas. The results showed that environmental educators incorporated new resources and ideas into their practice across all three programs. However, changes in the other practice elements varied among programs, which I attribute to different program goals and professional development interventions.

To explore the relationship between network properties, including in-degree, out-degree, closeness and betweenness centrality and tie strength, and practice change, I conducted correlation analysis. The results showed that in-degree centrality had a positive relationship with practice change in the state consortium and the online learning community, and other network measures only showed significant relationships with practice change in the state consortium. Finally, to better understand the process of change in networks and practice, I also conducted interviews in the state consortium and online learning community, and analyzed educators' mid-term and final reports in the fellowship program, which showed how the fellowship program and networking opportunities impacted their practices.

This dissertation explores dimensions of the communities of practice framework from social network and practice theory perspectives. It advances our understanding of the mechanisms of network formation, practice change, and the relationship between networks and practice change in environmental education. I also propose applications for professional development programs and recommendations for future research.

BIOGRAPHICAL SKETCH

Yue Li (Chinese: 李悦) was born in 1987 in Yunnan, China. Parents: Jianhong Li and Meizhi Yu. Yue earned a B.S. in Soil and Water Conservation at Beijing Forestry University in 2008, a M.S. in Natural Resources at Beijing Normal University in 2011, and is completing a Ph. D. at Cornell University.

Growing up in a remote mountain area in southwestern China, Yue could touch the natural world freely since early childhood. So climbing mountains, finding mushrooms, watching birds and picnicking in the woods are the best memories in her mind. After spending 17 years in natural areas, she went to Beijing for college in 2004. On the first day she went to Beijing Forest University, she joined the Scientific Exploration and Outdoor Life Association (SENOL). It was SENOL that opened ways for her to connect to various national and international environmental non-profit organizations. In 2005, leading a SENOL summer team as a freshman to the *Tetraena mongolica Maxim* Nature Reserve in Inner Mongolia triggered her concern about human impact on the environment. *Tetraena mongolica Maxim* has been endangered since the 1990s and is still threatened by goat browsing, logging, and pollution from mining. The conflicts between human needs and environmental conservation motivated her to explore a "win-win" solution.

These became her concerns for graduate study at Beijing Normal University in 2008. Her experiences in Dr. Qiong Gao's laboratory enabled her to access model simulations of social-ecological systems. For her Master thesis, she made several field trips to the northern farming-pastoral transitional belt, an ecologically sensitive area in China. She found the marked transformation between farmland and grassland due to different life styles of local people, which inspired her to study land-use spatial-temporal variations. Dr. Gao, who graduated from Cornell University in 1987, encouraged Yue to pursue a PhD in the US.

Environmental education has fascinated Yue since she started doing volunteer work at Jane Goodall Institute (JGI) in Beijing. In the summer of 2009, as a teaching assistant of the Eco-English project of JGI, she worked with two high school students from the US in environmental education at the Experimental School attached to Haidian Teachers Training College of Beijing. Once a week they offered a forty-minute interactive course in English for high school students addressing a range of topics including endangered species, moon bear farming, and energy consumption to global warming. This experience inspired her to continue participating in environmental education programs. In the summer of 2010, she worked as an intern at JGI helping the Green Life Action program promote low carbon life styles. She designed the toolkits for communities and companies focusing on a range of topics from energy and water saving, to green shopping to recycling. These experiences motivated Yue to learn more about environmental education.

In August 2011, Yue started her PhD under the supervision of Dr. Marianne Krasny in the Department of Natural Resources at Cornell University. Since then, she has been working for EECapacity, a national environmental education training program. Yue was a teaching assistant for the first online EECapacity course -- Urban Environmental Education -- taught by Drs. Alex Kudryavtsev and Marianne Krasny, which inspired her interests in online learning and social network analysis.

Through EECapacity online courses and workshops, Yue connected with environmental educators across the US, which helped her develop her research questions and identify research participants for her dissertation. Specifically, at the national training workshop in Washington D.C. in May 2012, Yue connected with state consortia leaders and piloted a study in California, Colorado and Maryland. Two co-leaders of the Pennsylvania State Consortium showed their

interests of examining professional networks in their consortium. Yue started working with them to conduct surveys and interviews, as well as attended one of their group meetings. In April 2014, Drs. Alex Kudryavtsev and Marianne Krasny facilitated another online learning community -- the Urban Environmental Education Project-based Online Learning Community -- in which participants co-authored on an eBook. Yue thought it was another great example of professional development programs for environmental educators and decided to conduct research with this group.

Thanks to the chance to participate in the North American Association for Environmental Education (NAAEE) annual conference in October 2011, Yue started to build her professional networks with scholars and environmental educators all over the world. Since then, she has been attending each of the NAAEE annual conferences. In summer 2014, she did an internship with NAAEE in Washington D.C. during which she helped organize workshops and write reports. She co-authored *State Environmental Literacy Plans, 2014 Status Report* with Judy Braus and others. Further, she helped to organize a weeklong workshop for Community Climate Change Fellowship at the National Conservation Training Center in West Virginia, and met with 26 fellows and conducted a network and practice survey in this group.

Yue also presented her research and served on the international advisory committee for the World Environmental Education Congress in Morocco in June 2013, and in Sweden in July 2015. She has been a reviewer for *Environmental Education Research* since she published her first English article there. Through these opportunities, she continues enhancing her academic skills and expands her professional networks internationally. In November 2015, Yue was invited by the World Wildlife Fund to give a talk at the Nature Education Forum in Hangzhou, China. That was her first formal environmental education conference in China; while there she

met with hundreds of passionate educators.

In fall 2015, Yue visited Dr. Nicole Ardoin's social ecological lab at Stanford University as an exchange scholar. It was a wonderful experience to connect to diverse scholars working on cross-disciplinary research. Also Yue audited Dr. Mitchell Stevens' course and connected to Lytics Online Learning Research Lab where she met several researchers working on online learning especially Massive Open Online Courses (MOOCs).

During Yue's recent two academic visiting trips back to China, she connected with many environmental education leaders, scholars and practitioners. Given the growing interests and support for environmental education in China, Yue is planning to conduct international programs and research to bridge environmental education communities in China and the US.

This work is dedicated to all environmental educators.

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I am very grateful to people, programs and organizations that supported me in completing this dissertation.

I would like to express my deepest gratitude to my advisor and committee chair Dr. Marianne Krasny for her advice and support all the way through my PhD. I thank her trust in recruiting me as her first Chinese student. Since I first came to Cornell in 2011, she has been encouraging me to think deeply and critically by asking great guiding questions. Thanks to her, I was brought into EECapacity project, based on which I conducted my research. The independent study on online learning with her motivated my interests in online learning research. Further, Dr. Krasny supported me to attend conferences to present my research and build professional networks all over the world. During my dissertation writing process, Dr. Krasny patiently reviewed my drafts again and again, and always provided helpful feedback immediately. She constantly inspires me to think creatively and keep up the hard work. I would not have done this dissertation without her.

I also want to thank my other committee members: Dr. Shorna Allred, Dr. Matthew Brashears and Dr. Justin Dillon. Dr. Allred provided thoughtful comments on my research ideas and proposals through Human Dimension Graduate Seminars. Through Dr. Brashears' social network theory course, I learned social network theories and applied social network analysis into my research. Dr. Brashears also offered helpful suggestion for my data analysis. Dr. Dillon broadened my views on professional development and communities of practice literature and offered insightful suggestions for my dissertation.

This dissertation would not have been possible without EECapacity project. I thank Judy Braus for her co-leadership on the project. Judy' engaging speeches always inspired me to keep

my passion in environmental education. In addition, I want to thank Anne Ferguson and Augusto Medina who coordinated professional development programs. I appreciate Jose “Pepe” Marcos-Iga’s support and have learned a great deal from him about storytelling in environmental education strategies. I also want to acknowledge Brian Hutchison who provided technical support for many EECapacity programs. Finally, I want to thank the evaluation team from the New Knowledge Organization including John Fraser, Rupanwita Gupta, Shelley Stern, and Ken Lo, who evaluated the EECapacity programs and shared the results with me.

My special thanks go to my research participants: Pennsylvania State Consortium (PA SC) co-leaders and members, Urban Environmental Education Project-based Online Learning Community (PLC) participants, and Community Climate Change (CCC) fellows. Particularly, the PA SC co-leaders Kacy Conely and Ruth Roperti sent out surveys to the PA SC members and invited me to join their webinars and face-to-face meetings. Robert Hughes, who was a participant in both the PA SC and PLC, invited me to visit his organization and sites, and shared with me his experience in environmental education. In addition, the PLC participants shared their experience with writing the eBook with me, and the CCC welcomed me at their workshops and shared their practices.

In summer 2014, as an intern at the North American Association for Environmental Education (NAAEE), I gained valuable knowledge on state environmental literacy plans and incredible experience networking with many other organizations in Washington D.C. In addition, I really appreciate the staff including Judy Braus, Drew Price, Christiane Maertens, Lori Mann, Christy Merrick, Macy Ocwieja, and Betty Olivolo who keep NAAEE running and are pleasant people to work with.

I am grateful to many professors at Cornell for offering courses, which helped me prepare

for conducting my research. For example, Dr. Nancy Well's *Research Methods in Social Sciences* helped me understand both quantitative and qualitative methods and their applications in education research. In 2012, I took my *Social Network Analysis for Social Sciences Research* course with Dr. Brian Rubineau, through which I was first exposed to social network theories and applications, and started learning R programing. Later Dr. Matthew Brashears' *Introduction to Network Theory and Methods* course helped me strengthen my understanding on network theories and informed my research design. I also want to thank Dr. Susan Fussell for teaching the *Computer-mediated Communication* course, Dr. Felix Thoemmes for teaching *Quantitative Research Methods*, Dr. Lindy Williams for teaching *Qualitative Research Methods*, and Drs. David Brown and Richard Stedman for teaching *Place, Community and Environment*. I am also thankful to statistical consultant Françoise Vermeylen for advice on statistical analysis over the years, and Lynn Johnson and Erika Mudrak for advice on statistical analysis during my dissertation revision.

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When I first came to Cornell five years ago, speaking English was a big barrier to me. I took classes and attended workshops from the Center for Teaching Excellence. I would like to thank Derina Samuel and Pauline Carpenter who helped me improve my English as well as teaching practice. Their support and encouragement enabled me to offer workshops as a graduate teaching assistant fellow to share my experience with students across the campus. I also took Spanish courses for three semesters at Cornell with Daniel Leraul and William Reyes-Cubides, who helped me to learn another useful language.

I thank Cornell's Graduate School and the Exchange Scholar Program, which supported me to visit Stanford University in fall 2015. I attended Dr. Nicole Ardoin's Social Ecology Lab

weekly seminar and Emmett Interdisciplinary Program in Environment and Resources seminar. I also audited Dr. Mitchell Stevens' *Research in Higher Education* course, through which I was connected to the Lytics Online Learning Research Lab. Further, I had chance to meet with Dr. Daniel McFarland and Dr. Lada Ladamic and discuss social network analysis in my research. These wonderful experiences expanded my professional networks and informed my research.

Many other individuals inspired me to keep passion in environmental education. When Dr. Arjen Wals visited Cornell in 2012, he shared ideas on social learning and online learning, which informed my first manuscript on interactive online learning. In November 2015, I accompanied Dr. Wals to attend the form the 2nd Nature Education Forum in China, through which I learned more about his academic experience and was inspired by his dedication to environmental education research. Further, I am always amazed by the way Akiima Price engages local communities. In summer 2014, Akiima took me to visit a community garden practice in Baltimore. That was the first time I closely got to know a low-income community and worked with local community members to design a community garden. I was truly impressed by how nature could bring people together to share and mitigate social problems. I also want to thank several other scholars with whom I exchanged ideas at conferences, for example, Drs. Martha Monroe, Alan Reid, Paul Hart, Charlotte Clark, Joe Heimlich, and Olivia Aguilar.

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me stay calm, overcome challenges and complete this dissertation.

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CHAPTER 1

INTRODUCTION

Overview

The field of environmental education strives to develop innovative practices to address equity, climate change, and other social and environmental issues (Monroe & Krasny, 2014). Research on social innovations has demonstrated that innovations are likely to arise when people communicate with other and share diverse perspectives (Biggs, Westley, & Carpenter, 2010). Thus, from 2011 to 2016, Cornell University conducted Expanding Capacity in Environmental Education (EECapacity), EPA's national environmental education training program, which offered training for environmental education and related professionals through face-to-face workshops and online courses and learning communities with a goal to foster networking and innovative practices. Rather than disseminating established practices to educators, EECapacity professional development programs are based on the hypothesis that creating learning communities for exchange of ideas and resources among educators holding different perspectives and practices will lead to innovations in educational practice (cf. Mulgan, Tucker, Ali, & Sanders, 2007). However, we know little about the impact of professional development interventions that foster such communications and sharing on social innovation in environmental education. The goal of this research was to explore the influence of professional development programs that emphasize professional networking on environmental educators' networks and practice change or innovation. In this introductory chapter, I provide an overview of my research questions, theoretical framework, EECapacity, study participants and program intervention, and methodology.

Research questions

To enhance our understanding of the effect of professional development programs on network and practice change, and of the relationship between network changes and practice change in environmental education, I conducted research that is described in the three core chapters of this dissertation. Chapter 2, "Development of Professional Networks among Environmental Educators," examines network structure and formation processes in learning communities. Specifically, this chapter addresses the research questions: 1) what were the characteristics of networks in three communities of practice? 2) What were the processes by which professional networks emerged in these communities? Chapter 3, "Practice Change in Environmental Education," applies practice theory to investigate change of practice elements in environmental education through face-to-face and online professional development activities. Specifically, this chapter addresses the research question: How did environmental educators change their practice through participating in communities of practice? Chapter 4, "Professional Networks and Practice Change in Environmental Education," explores the relationship between networks and practice change. Specifically, this chapter addresses the research question: What was the relationship of network structural properties and tie strength to change of practice elements among environmental educators participating in communities of practice?

Theoretical framework

Overview

In addressing questions about the role of professional development and networks on practice change, I apply multiple theoretical lenses including communities of practice, social networking, professional development, and practice theory (Figure 1and Table 1).

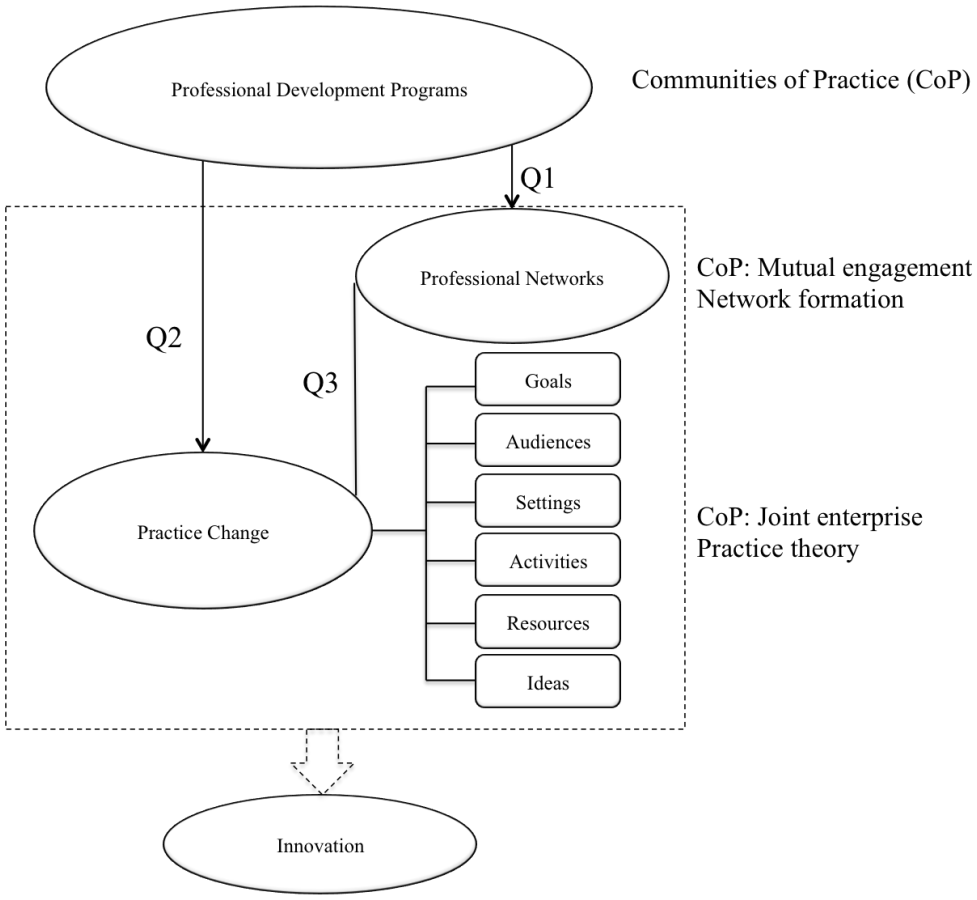
I apply communities of practice as an overall framework to describe the environmental

educators' learning communities developed through professional development programs that emphasize exchange of ideas about practice among educators. Wenger (1998) proposed communities of practice as a means to examine social learning and interactions among individuals. Rather than an isolated process, learning is a social activity that is situated in a community of learners (Wenger, 1998). In chapter 2, I examine educators' professional networks for interacting and exchanging ideas and practice, which reflects the first dimension of communities of practice, mutual engagement. In chapter 3, I investigate educators' practice change, which reflects the second dimension of communities of practice, joint enterprise. Finally, chapter 4 explores the relationship between networks and practice change, which reflects the interaction of the mutual engagement and joint enterprise. I do not directly address the third dimension of communities of practice, shared repertoire, although the educators participating in EECapacity shared resources through different platforms and in many cases created additional resources.

The theory of communities of practice speaks to many aspects of professional learning within groups, such as groups of teachers, yet it does not specifically examine how educators interact with each other to exchange ideas for their practices. Examining how educators are connected provides insights into how information is being shared in communities of practice. Investigating how educators change their practice sheds light on the impact of communities of practice on individual practice. Thus, the communities of practice framework is complemented by network and practice theory. Together these conceptual frameworks constitute my theoretical approach to understanding how environmental educators exchanged information and changed their practice through networking in communities of practice.

Below I review literature on communities of practice and its implications in education

especially teachers' professional development. Then I discuss how the concept of communities of practice can be used to guide my overall research and how it connects to network and practice theory specifically to address my research questions in each chapter. Here I focus on communities of practice and its connections with other theories, and leave the details of the other theories in the respective chapter.



Q1: How did environmental educators develop their professional networks? Q2: How did environmental educators change their practice? Q3: What was the relationship between networks and practice change?

Figure 1. Theoretical framework.

Table 1. Framework table

Theories	Research Questions	Measurements	Analyses
Communities of practice: Mutual engagement Social network theory: network formation Teacher development model: social development	1) What were the characteristics of networks in three environmental educator learning communities? 2) What were the processes by which professional networks emerged in these communities?	Network surveys Interviews (PA SC and PL) Reports (CCC)	Social network analysis Exponential random graphs models Content analysis
Communities of practice: Joint enterprise Practice theory Teacher development model: professional development	How did environmental educators change practice elements as a result of participating in professional development programs	Surveys - Check box questions - Likert-scale questions Interviews (PA SC and PL) Reports (CCC)	Linear mixed-effects models Content analysis
Communities of practice: interaction of mutual engagement and joint enterprise Social network theory Innovation theory	What is the relationship of network centrality (in-degree, out-degree, closeness and bewteenness) and tie strength to practice change?	Surveys - Check box questions - Likert-scale questions Interviews (PA SC and PL) Reports (CCC)	Correlation analysis Content analysis

PLC: Urban Environmental Education Project-based Online Learning Community
CCC: Community Climate Change Fellowship Program
PA SC: Pennsylvania State Consortium

Communities of practice

At the group level, each EECapacity professional development program created a community of practice for educators to exchange ideas. Drawing from situated learning theory that considers how individuals' cognition and meaning are socially and culturally constructed through becoming part of a community (Lave & Wenger, 1991), Wenger (2015) defined communities of practice as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". Three key components of a community of practice include mutual engagement, joint enterprise and shared repertoire (Wenger, 1998). Mutual engagement is about the relationships among participants, through which they interact and negotiate meanings with each other. Joint enterprise is the process in which participants work toward a common goal and develop mutual accountability. Shared repertoire represents "routines, words, tools, ways of doing things, stories, gestures, symbols, genres, actions or concepts that the community has produced or adopted in the course of its existence, and which have become part of its practice" (Wenger, 1998, p. 83).

Communities of practice could be developed through professional development programs that emphasize exchange of ideas about practice among educators. For example, mutual engagement can be achieved by networking among educators through professional development programs. By participating in professional development activities, educators interact to create a joint enterprise, in my case, to conduct or improve environmental education practices. Finally, a shared repertoire can be reflected by the information and resources shared through different platforms, in my case, meetings, workshops and Facebook groups, as well as collaborative projects such as eBooks co-authored by participants.

The concept of communities of practice has been applied in education to examine

teachers' interactions in schools (Wenger, 2015). Research exploring the process of developing a community of practice among teachers has shown that teachers shared their knowledge and teaching experience (Palincsar, Magnusson, Marano, Ford, & Brown, 1998) and developed networks for the exchange of resources and expertise (Barab, MaKinster, & Scheckler, 2003; Penuel, Riel, Krause, & Frank, 2009). Such communities of practice provide a well supported environment in which teachers receive and reflect on feedback about teaching (Akerson, Cullen, & Hanson, 2009). A teachers' community of practice may also help teachers improve their teaching practice (Bannister, 2015; Lotter, Yow, & Peters, 2014; Pharo, Davison, McGregor, Warr, & Brown, 2014), sustain teachers' learning over time (Chalmers & Keown, 2006), and encourage collaboration (Park, Steve Oliver, Star Johnson, Graham, & Oppong, 2007). In particular, Little (2002) found that teachers' communities of practice could supply intellectual, social and material resources for teacher learning and innovations in practice. Further, Rogers (2011) found that developing a community of practice supported teachers' implementation of curriculum. However, most of these studies relied on qualitative methods to understand the formation and outcomes of communities of practice. Little is known the *process* of how teachers interact with each other and develop professional networks for exchanging ideas and practice through communities of practice.

Studies applying the communities of practice framework in environmental education have focused on students' learning process. For example, Hogan (2002) looked at students' learning and development as environmental practitioners through communities of practice in school and community settings. Aguilar and Krasny (2011) used the specific dimensions of joint enterprise, mutual engagement and shared repertoire to examine learning process in after-school environmental education programs, and found that mutual engagement was often achieved when

the students interacted to create the joint enterprise, which reflects the interdependence of communities of practice dimensions (Wenger, 1998). I found no studies that applied communities of practice to professional development in environmental education.

Critiques of communities of practice

Scholars in different fields have provided critiques of the communities of practice framework. Several researchers have argued that the theory of communities of practice does not address power and inequality issues (Fox, 2000; Roberts, 2006), and thus is difficult to apply in practice (Wenger, 2010). Roberts (2006) further questioned the size and spatial reach of communities of practice. He pointed out that the flexible boundaries between communities of practice lead to difficulties in identifying and distinguishing among them.

In addition, the focus of communities of practice framework has shifted from "legitimate peripheral learning" through interactions between novices and experts (Lave & Wenger, 1991) to individual learning and identity development (Wenger, 1998), and expanded to knowledge management in organizations (Wenger, McDermott, & Snyder, 2002). L. C. Li et al. (2009) argued that a community of practice is similar to or overlaps with a support group, a network or a multidisciplinary team. Thus, the concept of communities of practice lacks a consistent interpretation, which results in difficulties in describing and developing such communities (Cox, 2005; L. C. Li et al., 2009). Although Wenger (1998, p. 125) summarized 14 indicators for identifying a community of practice, these indicators are abstract and hard to apply and interpret. These critiques point to difficulties in distinguishing communities of practice from other groups, examining the structure of communities of practice, and measuring the impact of communities of practice on individuals' learning and practice.

Social network analysis

Teacher professional networks, through which teachers share and exchange ideas for their teaching practices, could function as communities of practice (Inman, Mackay, & Rogers, 2011). Social network analysis can be used as a tool to examine educators' mutual engagement in communities of practice. Social networks, which are a form of social relationships, or "ties," can facilitate information transfer, and therefore can play a key role in the generation and dissemination of educational and other social innovations (Abrahamson & Rosenkopf, 1997; Moore & Westley, 2011). Previous studies have applied social network analysis to measure characteristics of teachers' face-to-face networks (Penuel, Sun, Frank, & Gallagher, 2012) and online learning networks (Cela, Sicilia, & Sánchez, 2015). Informed by studies using social network models to explore online learning network formation mechanisms (Joksimović et al., 2016; Kellogg, Booth, & Oliver, 2014), I used social network analysis and exponential random graph models to examine factors influencing the building of educator networks in three professional development programs. I review the literature on social network analysis and network formation in depth in Chapter 2.

Professional development

Communities of practice contribute to educators' social and professional development. B. Bell and Gilbert (1996) considered social development, or interaction and collaboration, as a key component of teacher development. In my study, social development occurred through workshops and online platforms and enabled educators to build networks. The social development then facilitates professional development, which in my study is defined as educators adapting ideas learned through the networking activities into their practices. This process also reflects Guskey's (2000) model of evaluating professional development, level 4:

participants' use of new knowledge and skills in practice. Most of the empirical studies that applied professional development models to measure teaching practice focused on classroom teaching and did not investigate practice in depth. I will discuss professional development in more depth in chapter 3.

Practice theory

While the communities of practice framework addresses group level engagement and shared goals, it does not provide details for examining specific practice at the individual level. One dimension of communities of practice, joint enterprise, is the process in which participants work toward a common goal and develop mutual accountability. However it is not clear how this process can be measured and its impact on individuals' practice. Such individual environmental education practice can be conceptualized by practice theory, which considers practice as core unit of analysis and suggests using elements to construct a practice (Reckwitz, 2002). I measured elements of environmental education practice including goals, audiences, settings, activities, resources and ideas before and after the professional development programs. I report changes in practice as a result of professional development activities in Chapter 3.

Professional Development, Networks, and Practice Change

In Chapter 4, I explore the relationship between the development of professional networks and practice change as a result of professional development in environmental education. Although I found no studies linking social network and practice change in education, I draw on studies that showed the impact of network structure on students' academic achievement (Cho, Gay, Davidson, & Ingraffea, 2007) and teacher outcomes including classroom instruction (Penuel et al., 2012) and perceptions of innovative school climate (Moolenaar, Daly, Cornelissen, et al., 2014)

The goal of the professional development programs I examined was to facilitate diverse groups of educators exchanging ideas in order to create innovative practice. We used professional development programs as interventions to examine educators' practice change and innovation. An external evaluation team evaluated the effectiveness of the programs in terms of participants' satisfaction and learning experience. In my study, rather than evaluating the effectiveness of the professional development programs, I focused on practice change, which may indicate innovation. However, because I can't judge the quality of the environmental education practice before the program, I do not pass judgment on educators' success or failure by the degree to which they have changed their practice as a result of the professional development programs. In the Conclusion, I address some of the limitations of my measures of practice change and innovation.

Background of EECapacity

Nearly thirty years ago, UNESCO (1990) identified the preparation of environmentally literate teachers as a top priority for improving environmental education. In 1992, the United States (US) Environmental Protection Agency (EPA) established the North American Environmental Education Training Program, with a goal to offer professional development and strengthen the field of environmental education. Through partnerships with the government, university, private and non-profit sectors, EPA's program has provided training using face-to-face workshops and increasingly online courses and learning communities.

In 2011, the Expanding Capacity in Environmental Education Project -- EECapacity -- became the fifth phase of US EPA's National Training Program. The goal of the project is to strengthen the field of environmental education so that it more closely reflects the urban demographics of North America. As over 80% of the US populations live in cities, a need exists

to create innovative environmental education programs in urban areas that reflect these changing urban demographics. EECapacity draws from the social innovation literature, which suggests that innovations in educational practice emerge through creating platforms for exchanging ideas and resources among educators holding different perspectives and practices (cf. Mulgan et al., 2007).

The EECapacity project provides a series of face-to-face and online professional activities such as state consortia, online courses and fellowship programs primarily for two types of educators: traditional environmental educators who work in more pristine settings with the goal to change students' environmental behaviors; and an emerging group of urban educators who use environmental activities to build academic and social skills among urban youth and to enhance community and environmental well-being. Since 2011, EECapacity has supported 11 state consortia to build environmental education state capacity by connecting environmental educators and youth and community development professionals working in formal and non-formal educational settings. In addition, EECapacity has provided 20 online courses covering topics such as urban environmental education, climate change education, environmental education research, bridging communities in environmental education, and using technology in environmental education. Further, three project-based online learning communities involved education and youth development professionals in producing eBooks on measuring environmental education outcomes, urban environmental education, and "EE en Española." Further, EECapacity funded two fellowship programs. The Community Climate Change Fellowship program involved a diverse group of educators and community leaders working to address climate change issues in their communities. The "Train the Trainers' Trainers" Fellowship program was specifically designed for educators who were interested in providing

online learning opportunities for other environmental education and youth development professionals.

Participants and program intervention

In this section, I describe the participants and professional development intervention for each program (Table 2 and Table 3). The professional development programs that are the focus of this study include: Pennsylvania State Consortium (PA SC), Urban Environmental Education Project-based Online Learning Community (PLC), and Community Climate Change Fellowship (CCC). All three programs brought together environmental educators from diverse backgrounds and encouraged interactions among educators, but varied in online and face-to-face professional development activities and outcomes (Table 3).

Table 2. Descriptive statistics for participants in each professional development program.

	Pennsylvania State Consortium	Project-based Online Learning Community	Community Climate Change Fellowship
Number of participants	27	43	26
First survey respondents (response rate)	23 (85%)	38 (88%)	26 (100%)
Second survey respondents (response rate)	19 (70%)	32 (74%)	26 (100%)
Gender			
Female	21 (78%)	32 (74%)	17 (65%)
Male	6 (22%)	11 (26%)	9 (35%)
Race			
White	20 (74%)	30 (70%)	15 (58%)
Non-white	7 (26%)	8 (18%)	11 (42%)
Not reported	-	5 (12%)	-
Age			
Mean	-	45	40
Working experience in environmental education			
< 10 years	-	20 (47%)	11 (42%)
>= 10 years	-	18 (42%)	15 (58%)
Not reported		5 (12%)	-

Note: The first survey was conducted in the beginning of each program, and the second survey was conducted after each program.

Table 3. Professional development activities and outcomes in each program

Programs	Pennsylvania State Consortium	Project-based Online Learning Community	Community Climate Change Fellowship
Activities	Face-to-face meetings Webinars Facebook group	Webinars Facebook group	Weeklong workshop National conference Webinars Facebook group
Outcomes	New leadership	eBook	Action projects

Pennsylvania State Consortium (PA SC)

The PA SC was one of 11 state consortia, which were supported by EECapacity to build environmental education state capacity by connecting environmental educators and youth and community development professionals working in formal and non-formal educational settings. In 2012, I conducted a pilot study with three state consortia from the first year of EECapacity: California, Colorado, and Maryland. I conducted retrospective network surveys with members from these three states after their professional development activities and received on average 50% response rate from each state. The pilot study helped me improve the social network survey that I used in my dissertation research. Later I conducted surveys and interviews with the PA SC from the third year of EECapacity.

PA SC started in spring 2014 and created a community for 27 educators and youth and community development professionals (21 females and 6 males, 19 white and 7 non-white) from community development organizations, professional associations, nature centers, state agencies, schools, parks, and other organizations in Pennsylvania. By creating a learning community for the participants to share and exchange ideas, the PA SC was trying to build a new leadership structure for environmental education in Pennsylvania to engage the youth and community development professionals. Two co-leaders, one from the Pennsylvania Association for Environmental Education and the other from the Pennsylvania Statewide Afterschool and Youth

Development Network, co-wrote the grant to EECapacity for their consortium professional development activities and recruited three additional leadership team members and 22 consortium members.

Throughout 2014, the PA SC conducted the following professional development activities: four statewide face-to-face meetings and one regional face-to-face meeting, eight webinars to share members' programs or listen to presentations by guest speakers during the months without face-to-face meetings, and a Facebook group for members to share information and resources created by leadership team member (PA-RH). In addition, the PA SC made a booklet with a description of each member to help members get to know each other. The PA SC members did not have structured assignments or collaborative projects during the professional development program period. After the one-year program, the group decided to continue sharing through conference calls, and to seek funding to organize additional face-to-face workshops.

Like other state consortia, the PA SC created a community of practice, through which the participants developed professional networks for exchanging ideas for their practice. Mutual engagement was achieved by interactions among the PA SC participants. Joint enterprise was reflected by the common goals to connect two types of professionals and improve their practice. The participants developed shared repertoire by attending quarterly face-to-face meetings and monthly webinars, as well as exchanging resources through Facebook group and emails.

The PA SC was similar to other EECapacity state consortia, but may not represent all the state consortia. I chose the PA SC for logistical reason in that I was able to be in touch with their leadership team, who were willing to cooperate and send out the surveys to their state consortia participants. The leaders allowed me to conduct a network survey at the beginning of their program in March 2014, and a network and a retrospective practice change survey after the

program in December 2014. Further, I conducted interviews with 5 participants in March 2015.

Project-based Online Learning Community (PLC)

The PLC was the second EECapacity online learning community with a collaborative writing assignment. The aim of the PLC was to increase educators' capacity to use environmental educational programs to foster urban sustainability and human wellbeing in response to social and environmental change in cities. A PLC leader hired by Cornell University facilitated the PLC from April-December 2014. Out of 94 environmental educators and community leaders initially signed up to join the PLC, 43 participated (mean 45 years old, 32 females and 11 males, 30 white and 8 non-white, 20 educators with less than 10 years working experience in environmental education) in the PLC final project, which involved collaborating in small groups to write eBook chapters on urban environmental education issues and describing urban environmental education case studies (total 61 authors including 43 PLC participants, 2 facilitators and 16 other scholars and practitioners). These educators work in cities with youth and adults in urban planning programs, public schools, after-school programs, community and youth development organizations, faith-based groups, community-based environmental organizations, outdoor education programs, museum-based programs, botanical gardens and zoos, and university outreach and teaching programs. The PLC provided four kinds of professional develop activities: a Facebook group to share and exchange information and resources, a series of webinars, an online library of research articles and other resources, and editorial and idea support for 2-5 person teams writing eBook chapters.

The PLC created a community of practice, through which the participants developed professional networks for exchanging ideas for their practice. Mutual engagement was achieved by interactions among the PLC participants. Joint enterprise was reflected by participants'

common interests in conducing environmental education in urban settings. The participants developed shared repertoire by joining Facebook group discussion and monthly webinars, as well as writing eBook chapters. I conducted a network and practice survey of the PLC participants in the beginning of the program in April 2014, and after the program in March 2015. Further I conducted interviews with 7 participants in March 2015.

Community Climate Change Fellowship (CCC)

The Community Climate Change Fellowship (CCC) program began in June 2014. The goal of the program was to foster leadership, networking, innovation, and strategies for reaching new and under-represented audiences in local climate change education projects. The fellowship program brought together 26 educators and community leaders (average 40 years old, 17 females and 9 males, 15 white and 11 non-white, 11 educators with less than 10 years working experience in environmental education) from the US, Canada and Mexico who address climate change issues in their communities.

The CCC fellows participated in an intensive five-day workshop in June 2014, which focused on how to communicate strategically about climate change, work with communities, and leverage funds and other project support. Following the workshop, each fellow was expected to design an action project to address a community problem related to climate change. Eight out of 26 fellows incorporated climate change into existing school programs or curricula, 14 incorporated climate change into existing non-formal environmental education programs or developed new projects to fit existing goals of their organizations, and 4 started totally new projects. The group met again at a national conference in October 2014, to share their projects with each other and with a larger environmental educator audience. During the intervening months (June – December 2014), they interacted with each other through monthly conference

calls, webinars, emails, and a Facebook group. After December 2014, most of the fellows continued interacting on Facebook.

The CCC created a community of practice, through which the participants developed professional networks for exchanging ideas for their practice. Mutual engagement was achieved by interactions among the CCC participants. Joint enterprise was reflected by participants' common goals in developing climate change action plans. The participants developed shared repertoire by attending the workshop and conference, joining Facebook group discussion and participating in monthly webinars, sharing resources, and developing a website to share their projects. I conducted a network and practice survey of the CCC fellows in the beginning of the program in June 2014, and after the program in December 2014. I also examined the CCC fellows' mid-term and final project reports.

Methodology

I employed a positivist framework, and conducted mixed methods research to examine network and practice change. The positivist paradigm is referred to as the "scientific method" or "science research". According to Lincoln and Guba (1985, p. 29), Habermas proposed five central aspects of positivism including "objectivity, hypothetico-deductive theory, external lawlike relations, exact and formal language, and separation of facts from meaning. Positivist purists favor quantitative methods and believe that social observations should be treated as physical phenomena. However, Lin (1998) argued that qualitative work could be positivist when it "seeks to identify those details [about preferences, motivations, and actions that are not easily made numeric] with propositions that then can be tested or identified in other cases" (p. 163). In my research, I followed a deductive logic to test proposed practice elements based on a priori theory mainly by conducting quantitative methods, which falls under positivist paradigm.

Although I used qualitative methods including interviews and analyzing reports, the coding processes of the interview transcripts and reports were based on the predetermined practice elements rather than exploring emerging themes.

Johnson and Onwuegbuzie (2004) defined mixed methods research as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (p. 17), and suggested considering mixed methods research as a new methodological paradigm in educational research. Quantitative methods allow researchers to test theories, generate findings and make predictions, while qualitative methods enable researchers to require rich descriptions and understand complex phenomenon (Creswell, 2013). In complex research studies, using mixed methods could adopt the strengths of both methods to answer a broader range of research questions (Johnson & Onwuegbuzie, 2004), and provide triangulation to address validity issues (Jick, 1979). In my research, I mainly relied on quantitative methods to examine the change of network and practice as a result of professional development programs, and used qualitative methods to explore an in-depth understanding of these changes and provide triangulation to compare with the results from quantitative methods. Thus a mixed methods approach is appropriate to address the research questions in my dissertation.

As part of mixed methods, I conducted three case studies (Yin, 2011) using multiple sources of data to examine the impacts of different professional development programs on educators' network and practice change. I used within-case analysis to identify change of practice elements and cross-case analysis to identify common themes across cases. A case study approach, which is commonly used in environmental education research (Dillon & Reid, 2004), is most appropriate in this study because the questions have a level of complexity that requires

multiple data sources to gain an in-depth understanding. The incorporation of multiple data sources including surveys from all three cases, interviews from the state consortium and the online learning community, and reports from the fellowship program also provides a method of triangulation to address validity issues (Yin, 2013).

Studying these three different groups helps us to understand how educators develop networks and change practice elements for their environmental education and related programs across multiple settings. Each group or setting serves as a different case in which to test our ideas about networks and practice change. The intent of this study is not to compare the outcomes of the three cases per se, but rather to test our ideas across a range of settings in order to develop a more robust understanding of professional networks and practice change.

CHAPTER 2

DEVELOPMENT OF PROFESSIONAL NETWORKS AMONG ENVIRONMENTAL EDUCATORS

Abstract: Professional development programs provide an opportunity for environmental educators to develop networks to exchange ideas and practices in professional learning communities. Using the theory of communities of practice as a framework, the aim of this study is to investigate how diverse environmental educators develop professional networks for exchanging information among each other through online and face-to-face professional development activities. I conducted surveys and social network analysis in three professional learning communities including a state consortium with mostly face-to-face activities, an online learning community with only online interaction, and a fellowship program with both face-to-face activities and online interaction. The results showed that the networks in all three communities became denser after participating in the professional development programs. Further, I used exponential random graph models to examine factors that influence the network formation in each community. The results showed that professional development activities, including both face-to-face activities and online interactions, had a positive effect on the likelihood of network formation. The results help us understand the role of online and face-to-face professional development activities in the formation of professional networks that enable educators to share ideas and practices.

Key words: professional development, communities of practice, professional networks, online interaction, social network analysis, and ERGMs

Introduction

In the context of global environmental change and climate change in particular,

professional development for environmental educators is especially important to enhance educators' capacity to conduct environmental education practice (Monroe & Krasny, 2014). In addition to knowledge and skills acquisition, professional development can help educators exchange and adapt ideas to improve their practice (O'Donoghue & Russo, 2004). By creating professional learning communities, professional development programs encourage interactions among educators who share diverse perspectives, which may foster exchange of ideas and resources, and lead to emergence of innovative practices (Biggs et al., 2010). Such interactions and collaborations among educators not only could enable them to reflect on and improve their practices (Grossman, Wineburg, & Woolworth, 2001), but also contribute to their social development, which is a critical aspect of teacher development (B. Bell & Gilbert, 1996).

Wenger (1998) proposed communities of practice as a means to examine social learning and interactions among individuals. Rather than an isolated process, learning is a social activity that situated in a community of learners (Wenger, 1998). Such communities could be developed through professional development programs that emphasize exchange of ideas about practice among educators. The theory of communities of practice provides a framework to examine educators' professional networks through mutual engagement in communities (Wenger, 1998). Research applying the theory of communities of practice to examine teachers' learning and practice found that teachers developed networks for the exchange of resources and expertise (Barab et al., 2003), which may encourage collaboration (Park et al., 2007) and help teachers improve their teaching practice (Bannister, 2015; Lotter et al., 2014; Pharo et al., 2014).

Mutual engagement in communities of practice can be investigated in depth from a social network perspective. Researchers have used SNA to examine interactions among teachers (Eberle, Stegmann, & Fischer, 2015; Moolenaar, 2012; Penuel et al., 2012) including in online

settings (Cela et al., 2015). For example, studies focus on network characteristics and measure density and centrality in teachers' advice networks (Penuel et al., 2009) and in teachers' communication networks in online learning communities (Sing & Khine, 2006). These descriptive analyses provide an overview of network structure and teachers' positions in the networks.

A growing body of research has explored the factors that impact the development of teachers' networks using social network models (Frank, Lo, & Sun, 2014). Rivera, Soderstrom, and Uzzi (2010) categorized three major mechanisms of network formation including assortative, structural and proximity mechanisms. Studies found that assortative mechanisms such as teachers' demographics and structural mechanisms such as density and reciprocity impacted the formation of teachers' advice networks (Moolenaar, Daly, Sleegers, & Karsten, 2014; Penuel et al., 2010; Siciliano, 2015; Spillane, Hopkins, & Sweet, 2015). These studies relied on current existing advice networks. Further, Kellogg et al. (2014), examined formation of online communication networks among teachers participating in online courses and found core-periphery structure in teachers' online communities of practice. Such a network perspective on teachers' communities offers a useful lens for analyzing how educators interact with each other for exchanging idea and practices.

To enhance our understanding of the process of information exchange through communities of practice, I examined the development of educators' professional networks in three environmental education professional development programs. Specifically, using Wenger's (1998) communities of practice as a framework and social network analysis as an approach, I addressed two research questions: 1) what were the characteristics of networks in three environmental educator communities of practice? 2) What were the processes by which

professional networks emerged in these communities of practice? The results of this study help us understand how to plan interventions that enable diverse environmental educators to share resources and information, an important component of professional development.

Literature Review

Below I review literature on teacher learning communities, social network analysis in educational settings, and network formation. I start with the literature on learning communities for teachers and networked learning in online learning communities. I next examine how previous studies used SNA to understand teachers' interactions in professional communities and finally I explore network formation mechanisms.

Teacher learning communities

The term "learning community" became popular among educators in the 1990s (Graves, 1992). Lieberman and Miller (2008) defined a teacher learning community as an "ongoing group of teachers who meet regularly for the purpose of increasing their own learning and that of their students" (p. 2). Research has focused on professional learning communities that are created to establish collegial relationships and build capacity for change within schools (Blankenship & Ruona, 2007; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). In a professional learning community, "educators create an environment that fosters mutual cooperation, emotional support, and personal growth as they work together to achieve what they cannot accomplish alone" (DuFour & Eaker, 1998, p. xii). The literature on professional learning communities has focused on the role of school culture and leadership in building teachers' collaboration that in leads to school improvement, while the literature on communities of practice has focused on the role of social learning in the formation of new knowledge and improvement of practice (Blankenship & Ruona, 2007). In spite of different focuses, the common feature of these communities is the

interaction among teachers for exchanging information, creating collaboration and building support. Examining such teacher interactions is important to help us understand the information flow in teacher communities, which may influence the group performance, and individual learning and practice.

With the development of technology, social networking online platforms provide ways to create online learning communities to facilitate teacher professional development (Lock, 2006). Goodyear, Banks, Hodgson, and McConnell (2004) defined networked learning as learning in which information and communications technology is used to promote connections: between one learner and other learners; between learners and tutors; between a learning community and its learning resources" (p. 1). Such networked learning through interaction can provide a well supported environment for teachers to develop connections (Dresner & Worley, 2006; Duncan-Howell, 2010), promote peer learning (Holmes, 2013), knowledge sharing (Booth, 2012), and emotional sharing (Hur & Brush, 2009), and improve teaching practices (Fusco, Gehlbach, & Schlager, 2000). In addition, through online interactions, teachers can develop more diverse networks than they would in their everyday work environment and access resources not available locally (Schlager, Farooq, Fusco, Schank, & Dwyer, 2009). For example, learners developed professional connections through participating in Massive Open Online Courses (MOOCs) (Saadatmand & Kumpulainen, 2014). Y. Li, Krasny, and Russ (2014) found that environmental education professionals who interacted through an online course tended to develop networks offline.

Social network analysis

Social network analysis (SNA) offers a way to study interaction patterns in educational settings (McFarland, Diehl, & Rawlings, 2011; Moolenaar & Daly, 2012), and thus to understand

how information and resources flow in teachers' learning communities (Schlager et al., 2009). Researchers have explored ways to visualize professional development networks in order to identify existing networks (de Laat & Schreurs, 2013; Thompson et al., 2013). Studies have conducted social network analysis to describe network characteristics at the group and individual level.

At the group level, studies used density, reciprocity and transitivity to describe networks. Density measures the extent to which the participants in each group are connected among themselves (Wasserman & Faust, 1994). Studies used density to characterize teachers' networks. For example, Andrews, Conaway, Zhao, and Dolan (2016) found the density of faculty members' networks in some departments were relatively higher than that in other departments, indicating different levels of interactions in different departments. In online learning networks, studies examined online discussion interactions among teachers (Sing & Khine, 2006) Other studies on students, found that density of the online communication networks among students decreased over time (de Laat, Lally, Lipponen, & Simons, 2007a) and decreased as the group size became larger (Aviv, Erlich, & Ravid, 2008). Reciprocity measures the likelihood of participants to be mutually linked, and transitivity measures the tendency of two participants to be connected if they share a mutual neighbor (Wasserman & Faust, 1994). Aviv et al. (2008) found that observed values of reciprocity and transitivity were substantially higher than what would be expected by chance in online learning networks, which means that online communications tended to be mutual and transitive.

At the individual level, studies use in-degree, out-degree, closeness and betweenness centrality to characterize individuals' positions in networks. Degree centrality (Borgatti, 2005; Freeman, 1979; Knoke & Yang, 2008) measures the extent to which a participant connects to all

other participants, which indicates core, peripheral and bridging participants in the network. For example, Penuel et al. (2009) used in-degree centrality to describe teachers providing help to others, and out-degree centrality to describe teachers seeking help from others. Penuel et al. (2009) found that in-degree centrality was positively associated with teachers' perceptions of access to valued expertise. In an online graduate course, De Laat et al. (2007a) examined how online learning and tutoring patterns change over time by calculating participants' centrality. A student with higher in-degree centrality meant that the student received more comments from other students, which indicated the popularity of the student in the course. A student with higher out-degree centrality meant that the student made more comments to other students. Closeness centrality measures the extent to which a participant has short paths to all other participants (Freeman, 1979). A participant with higher closeness centrality has more direct, unmediated relationships with all other participants in the network. Betweenness centrality shows how often one participant is likely to be an important relay point between other participants (Freeman, 1979). An individual with high betweenness plays a bridging role to connect others and control communication of others (Freeman, 1979), which may exert interpersonal influence over others (Wasserman & Faust, 1994).

Network formation

Studying the mechanisms of teacher network formation can help us understand the internal structure of professional communities. Research has explored the mechanisms of tie formation in different kinds of networks such as friendships (Hallinan, 1978) and entrepreneurial collaboration (Ruef, Aldrich, & Carter, 2003). Rivera et al. (2010) categorized the processes of network formation into three mechanisms: assortative, structural, and proximity (see below).

Structural mechanisms explain the influence of network structure characteristics such as

reciprocity, transitivity, and existing relationships on network formation (Rivera et al., 2010). Studies found that people tend to make friends with people who have already named them in a longitudinal study (Hallinan, 1978) or respond to a received message online (Cheng, Romero, Meeder, & Kleinberg, 2011). Also people tend to connect to the friends of their friends (Granovetter, 1973) and the friendship persists over time if two individuals share a mutual contact (Martin & Yeung, 2006). In teachers' work related discussion or advice networks, studies found that teachers tend to build reciprocated connections to seek advice from each other (Moolenaar, Daly, Sleegers, et al., 2014; Siciliano, 2015). Studies on learners' interactions in MOOCs found that reciprocity was significantly associated with formation of communication networks, which indicated that learners tended to interact with peers who replied to their posts (Joksimović et al., 2016; Kellogg et al., 2014). Further, transitivity was significantly associated with formation of teachers' advice networks, which indicated that teachers tended to seek advice from those who shared a mutual connection (Siciliano, 2015). Aviv, Erlich, and Ravid (2005) also observed high transitivity in online learning networks with teamwork activities. Finally, the MOOCs studies found a negative relationship between in-degree centrality (popularity) and network formation, indicating the networks were not centralized on in-degree and most participants had similar levels of popularity (Joksimović et al., 2016; Kellogg et al., 2014).

Assortative mechanisms focus on individuals' attributes such as age, gender, race and education to examine how two individuals' similarities, or "homophily" and dissimilarities, or "heterophily," impact the likelihood of their forming a connection (Rivera et al., 2010). The principle of social homophily argues that people tend to choose others who are similar to them as friends (McPherson, Smith-Lovin, & Cook, 2001). For example, Wimmer and Lewis (2010) found racial homophily impacts friendship network formation on Facebook. In teachers' advice

networks, studies found that teachers tend to seek advice from other teachers who have the same gender (Frank & Zhao, 2005; Moolenaar, Daly, Sleegers, et al., 2014; Spillane, Kim, & Frank, 2012) and same race (Spillane et al., 2012), and teach the same grade (Frank & Zhao, 2005; Moolenaar, Daly, Sleegers, et al., 2014; Penuel et al., 2010; Siciliano, 2015). Further Penuel et al. (2010) found that participating in the same meetings increased the likelihood that teachers sought advice from one another. By investigating learners' communication networks in MOOCs, both Kellogg (2014) and Joksimovic (2016) found the impact of homophily in that the more successful learners tended to interact more often. However, Newman and Dale (2007) suggested individuals in a network, which tend to become more homogenous over time, might limit the diversity of the network.

In addition, heterophily plays a role in sharing ideas and information in collaboration networks. Teachers are more likely to seek advice from those who had more years of experience at school (Moolenaar, Daly, Sleegers, et al., 2014), those who were better at improving student achievement (Wilhelm, Chen, Smith, & Frank, 2016), those who had attended more professional development programs (Spillane et al., 2012) and those holding a leadership position (Moolenaar, Daly, Sleegers, et al., 2014; Spillane et al., 2015; Spillane et al., 2012). Teachers view attending professional development programs (Spillane et al., 2012) or holding leadership positions (Spillane et al., 2015) as indications of expertise. In online learning networks, Jiang, Fitzhugh, and Warschauer (2014) found that MOOC learners with high grades are more likely to form ties with learners with lower performance, and vice versa. This suggests that the discussion forum in online learning serves an important role in facilitating help seeking and promoting communication among learners.

Proximity mechanisms suggest that individuals tend to connect to others who are close to

them in geographic distance (Rivera et al., 2010). People tend to make friends with those who live physically close to them (van Duijn, Zeggelink, Huisman, Stokman, & Wasseur, 2003). Huang, Shen, and Contractor (2013) reported that individuals who were located closer to each other were more likely to interact with than those who were located farther away from each other in online gaming communities. In online learning networks, studies found that learners from the same location had a significant positive relationship with the likelihood of communicating with each other (Kellogg et al., 2014; Yuan & Gay, 2006). In contrast, Joksimović et al. (2016) found that learners from two countries were less likely to communicate with their domestic peers in a MOOC, indicating cross-country communications. Thus the impact of distance on tie formation varies depending on different types of connections and contexts.

Methods

This study used a mixed-methods approach including social network analysis, interviews, and content analysis of project reports to examine the characteristics, formation and change of networks over time among environmental educators in three professional development programs. Social network analysis, which is a research methodology that measures social relations and interactions (Scott, 2000), has been widely used in the social sciences (Borgatti, Mehra, Brass, & Labianca, 2009). Environmental educators' professional networks are one kind of social network. Thus it is appropriate to use social network analysis to examine educators' networks in this study.

Here I describe the social network surveys in the programs. Then I introduce social network measures at group and individual level, which are included in the models. Further, I explain the exponential random graph models (ERGMs). Finally, I talk about interviews and reports.

Participants

Participants for all three chapters in the dissertation are included in Chapter 1: Introduction. I use the term participants to refer to environmental educators and community development professionals in the study, including those in the Pennsylvania State Consortium (PA SC), Urban Environmental Education Professional Learning Community (PLC) and Community Climate Change Fellowship program (CCC).

Social network surveys

To investigate the change in professional networks, I conducted social network surveys (Appendix 1) with participants in the PA SC, PLC and CCC in the beginning and after the professional development activities. The network surveys asked participants to identify the individuals whom they went to for information, advice, or help for their environmental education programs. The participants in each program were asked to identify their contacts with each participant in the group from a given name list, which generated a whole network and showed how the network changed after the programs.

Social network measurements

To demonstrate how participants' networks change over time, I used the R *igraph* package (Csardi & Nepusz, 2006) to visualize the network data, and the R *sna* package (Butts, 2008) to measure network structural characteristics (Table 4). At the group level, density was calculated by the ratio of the number of ties in the network over the total number of possible ties between all pairs of nodes (Knoke & Yang, 2008; Wasserman & Faust, 1994). Reciprocity means that when there is a tie from A to B, then there is also a tie from B to A (Wasserman & Faust, 1994). It is the ratio of the number of relations, which are reciprocated (i.e., there is a tie in both directions) over the total number of relations in the network. Transitivity means that

when there is a tie from A to B, and also from B to C, then there is also a tie from A to C (Wasserman & Faust, 1994). It is the ratio of the number of transitive triads over the total number of possible transitive triads.

Table 4. Network measurements.

Measurement	Definition	Purpose
Group level		
Density	The extent to which the participants in each group are connected among themselves	Strength of the network
Reciprocity	The likelihood of participants to be mutually linked.	Interaction among participants
Transitivity	The tendency among two participants to be connected if they share a mutual neighbor	Balance of the network
Individual level		
In-degree centrality	The number of connections through which each participant gives out information to others.	Information provider
Out-degree centrality	The number of connections through which a participant seeks information.	Information seeker
Closeness centrality	The extent to which a participant has short paths to all other participants.	Middle of the network structure
Betweenness centrality	How often one participant is likely to be an important relay point between other participants	Brokers, connect other people

At the individual level, in-degree centrality refers to the number of connections through which each participant gives out information to others (Knoke & Yang, 2008). It identifies the central players who provide resources to others. Out-degree centrality calculates the total number of connections through which a participant seeks information (Knoke & Yang, 2008). Closeness centrality indicates how close a participant is to all other participants, and is calculated by the inverse of the average length of the shortest paths to/from all the other participants in the network (Freeman, 1979). The rationale for including closeness centrality is because the goal of the professional development program was to foster information exchanging among educators

and generate innovative practice. The educators with higher closeness centrality may be more likely to have direct and quicker access to resources, which may lead to practice change. Due to isolates in the PA SC pre-program network, and the PLC and CCC pre- and post-program networks, I used an alternative form of closeness calculated by the sum of the inverse distances to other participants (Gil & Schmidt, 1996). Betweenness centrality indicates brokers connecting other people and is calculated by the number of shortest paths going through one participant (Freeman, 1979). The state consortium had a leadership team of 5 educators who helped connect different types of education and youth development professionals in the state (brokers). Thus betweeness centrality may associate with the PA SC participants' practice change.

Exponential random graph models (ERGMs)

Exponential random graph models (ERGMs), also known as *p** models, can be used in SNA to predict the likelihood of tie formation (Robins, Pattison, Kalish, & Lusher, 2007). An ERGM is similar to a logistic regression model, but controls for the interdependency of the networks. In this study, I used R *ergm* package (Hunter, Handcock, Butts, Goodreau, & Morris, 2008) to explore three mechanisms of network formation (Rivera et al., 2010). ERGMs have been widely used in examining students' friendship network formation (McFarland, Moody, Diehl, Smith, & Thomas, 2014; Webb & Engar, 2016). Studies also applied ERGMs to explore advice network formation in elementary school among teachers (Siciliano, 2015) and online communication networks in MOOCs among students (Joksimović et al., 2016; Oleksandra & Shane, 2016) and teachers (Kellogg et al., 2014).

The structural mechanisms include reciprocity, transitivity and in-degree centrality (popularity) of post programs (Table 5), which were included in the models by using terms *mutual*, *ttriple*, *and idegreepopularity* in *ergm*. Although 16 types of triads are possible, in

educators' advice networks, educators tend to ask advice from those who have more resources, or two educators may be likely to connect to the same educator who holds resources. For example, if A went to B for resources and B went to C for resources, it is likely that A would also connect to C to gain resources. In the PLC in particular, educators formed small groups to write eBook chapters. Two educators who were interested in same topics might be likely to connect to the third educator who had the same interests. Thus, I chose transitivity as a network formation mechanism in this study. Instead of simply counting the number of transitive triads in the network, studies usually use the *geometrically weighted edgewise shared partner distribution (GWESP)* to measure transitivity (Hunter et al., 2008). However, given the small size networks in my study, the likelihood of a tie embedding in multiple transitive triads was small. Thus I chose using the ERGM term *transitive* to count the number of transitive triads.

Table 5. ERGM attributes measured for each of the three programs.

	Pennsylvania State Consortium	Project-based Online Learning Community	Community Climate Change Fellowship
Structural mechanisms			
	Reciprocity	Reciprocity	Reciprocity
	Transitivity	Transitivity	Transitivity
	Popularity	Popularity	Popularity
Assortative mechanisms			
Node attributes	Gender	Gender	Gender
	Race	Race	Race
	Webinar attendance	Work Year	Work Year
	Meeting attendance	Facebook post	Facebook post
		Facebook comments - Participants	Facebook comments - Participants
		Facebook comments - Facilitators	Facebook comments - Facilitators
Edge attributes	Webinar network	Facebook network	Facebook network
	Meeting network	Co-authorship	
	Pre-program network		
Proximity mechanism			
Edge attribute	Geographic distance	Geographic distance	Geographic distance

The assortative mechanisms include different node attributes (individual's characteristics)

and edge attributes (tie's characteristics) (Table 5). In PA SC, the node attributes include gender, race, size of organization, the number of webinars attended, and the number of meetings attended. The race groups were categorized into two groups: white and non-white. The edge attributes include webinar network, meeting network and the pre-program network. Webinar network and meeting network mean whether or not two participants attended the same webinar or meeting. They are affiliation networks, which were transformed into one-mode structure by projection. Unlike participants in the PLC and CCC, some participants in the PA SC were already connected to each other before the professional development program. This provided an opportunity to examine pre-program network as an assortative mechanism of network formation.

In the PLC and CCC, the node attributes include gender, race, years of environmental education work experience, and Facebook posts and comments on other participants' and facilitators' posts (see more details below). The race groups were categorized as white and non-white. The number of working years in environmental education was categorized into two groups: less than 10 years, and equal or more than 10 years.

The edge attribute was Facebook communication network, which was captured by the online commenting network from the Facebook group. For example, if a participant commented on another participant's posts, there would be a connection between these two participants. The PLC has an additional edge attribute -- co-authorship. Two participants connected with each other if they co-authored a book chapter as part of an eBook produced by the PLC members.

The proximity mechanism was geographic distance measured by the longitude and latitude of each participant's working location. The geographic distance between any two participants was continuous.

Facebook data collection

Participants in the PLC and CCC used a Facebook closed group to interact with each other. Although the PA SC also had a Facebook group, few participants engaged in the online discussion. I analyzed the PLC and CCC participants' Facebook interactions to identify participants' online interactions. I used Facepager to capture Facebook data from the PLC and NCapture[1] to capture Facebook data from the CCC. The number of posts and comments from the participants were coded as continuous variables. Because interactions with facilitators were less frequent, the comments to and from the facilitators were coded as binary variables. Specifically, if a participant commented on a facilitator's post, it was coded "comments to facilitators-present." If a participant received a comment from a facilitator, it was coded "comments from facilitators-present" (Table 6).

Table 6. Descriptive statistics for Facebook data in Project-based Online Learning Community and Community Climate Change Fellowship.

		Project-based Online Learning Community	Community Climate Change Fellowship
Facebook Posts	Total	180	193
	Mean	4.19	7.42
	Median	2	4.5
	Range	0-27	0-35
Facebook Comment - participants			
	Total	289	167
	Mean	6.72	6.42
	Median	5	4
	Range	0-42	0-29
Facebook Comment - facilitators			
	To facilitators Present	18	18
	To facilitators Not present	25	8
	From facilitators Present	10	13
	From facilitators Not present	33	13

To construct a Facebook communication network, I captured Facebook data based on

[1] NCapture is preferred because it allows capture of well-organized data frame from Facebook, which can be saved as a .csv file separating names, posts and comments in different columns. But due to stricter privacy settings in the PLC, NCapture could not capture data its Facebook data. Thus I had to use Facepager to capture data in the PLC and then organize data in R.

who commented on whose posts. If A commented on B's post, there was a tie from A to B. However I did not capture who commented on whose comments. Given that in most cases educators commented on each other's original posts rather than on each other's comments, I focused on poster-commenter interactions rather than commenter-commenter interactions. In the ERGMs, the Facebook ties among participants were weighted by the number of comments.

Interviews and Reports

To gain a deeper understanding of how participants developed their networks, I conducted semi-structured interviews with 5 participants from the PA SC, and 7 participants from the PLC after the professional development activities (Appendix 2). Two interviewees were in both the PLC and PA SC. I used a purposive sample strategy; I chose interview participants who, based on their network surveys, added contacts a lot, some, and not at all. I asked participants if and how participation in professional development activities (workshops, webinars, Facebook group discussion and other program activities) allowed them to develop networks with other educators and instructors. I transcribed the interviews and coded the transcripts by identifying network related quotes that showed how participants interacted with each other and exchanged ideas (Saldaña, 2009).

Because the project external evaluator had interviewed 12 participants from CCC, I was asked not to conduct further interviews with this group. However, I coded the individual mid-term reports submitted to the program leaders in the middle of the program (September, 2014) from 23 participants and 14 final project reports submitted to the program leaders after the program (January, 2015). In their reports, the CCC participants described their climate change education projects and reflected on how the training program or the fellowship network helped them develop their projects. Specifically I looked at two questions asked in the report: 1) Tell us

how you have used the fellowship training opportunities or the fellowship network to improve or adjust your fellowship project; and 2) Share a story that illustrates something you have learned or something that was meaningful for you personally or professionally. Although the questions were not directly about network formation, the CCC participants mentioned how they developed professional networks as a result of the training program.

Validity

Content validity is "the degree to which elements of an assessment instrument are relevant to and representative of the targeted construct for a particular assessment purpose" (Haynes, Richard, & Kubany, 1995, p. 238). I addressed content validity by using previous studies and expert opinions to develop the network surveys. Convergent validity is the degree to which different methods that measure the same traits produce similar results (Campbell & Fiske, 1959). I addressed convergent validity by comparing results from network surveys and interviews and reports.

Results

The PA SC had a total of 27 participants. The response rates were 85% in the survey conducted in the beginning of the program and 70% in the survey after the program. Among those who responded to the surveys, 17 (62%) responded to both surveys. Among 43 participants in the PLC, 38 (88%) responded to the survey conducted in the beginning of the program and 32 (74%) responded to the survey after the program. Among those respondents, 30 (70%) responded to both surveys. In the CCC, the response rates were 100% for both surveys.

Cross tabulation and chi-square analysis in the PA SC and PLC showed that there were no significant differences between participants who responded to the survey and those who did not respond to the survey in terms of their gender, race and years of working experience in

environmental education in both surveys.

Network characteristics

Group level network measurements

The density values showed the overall connection between the participants in each program before and after the professional development activities (Table 7). The density in each group increased after the professional development activities, indicating that the participants had more connections among each other after participating in the program. The density value increased from .16 to .37 in the PA SC, from .01 to .04 in the PLC, and from .02 to .50 in the CCC. The PA SC had a higher pre-program density (.16) relative to the PLC (.01) and the CCC (.02), indicating that the participants in the PA SC had more pre-program connections than other two groups. After the program, the density of the CCC (.50) was the highest among three groups, indicating that the participants in the CCC developed more connections through the professional development activities than the other two groups. Although density was relatively high in the PA SC after the program (.37), this represents a net change of .21 units. Density was the lowest after the program in the PLC (.04).

Individual level network measurements

The in-degree centrality measures how many participants nominated a participant as an information provider and the out-degree centrality measures how many participants from whom a participant sought information. The mean values of in-degree and out-degree centrality increased across all three groups after the professional development activities (Table 7) indicating participants had more connections among each other after the professional development activities. The mean of degree centrality increased from 4.15 to 9.63 in the PA SC (Figure 2), from .21 to 1.67 in the PLC (Figure 3), and from .39 to 12.00 in the CCC (Figure 4).

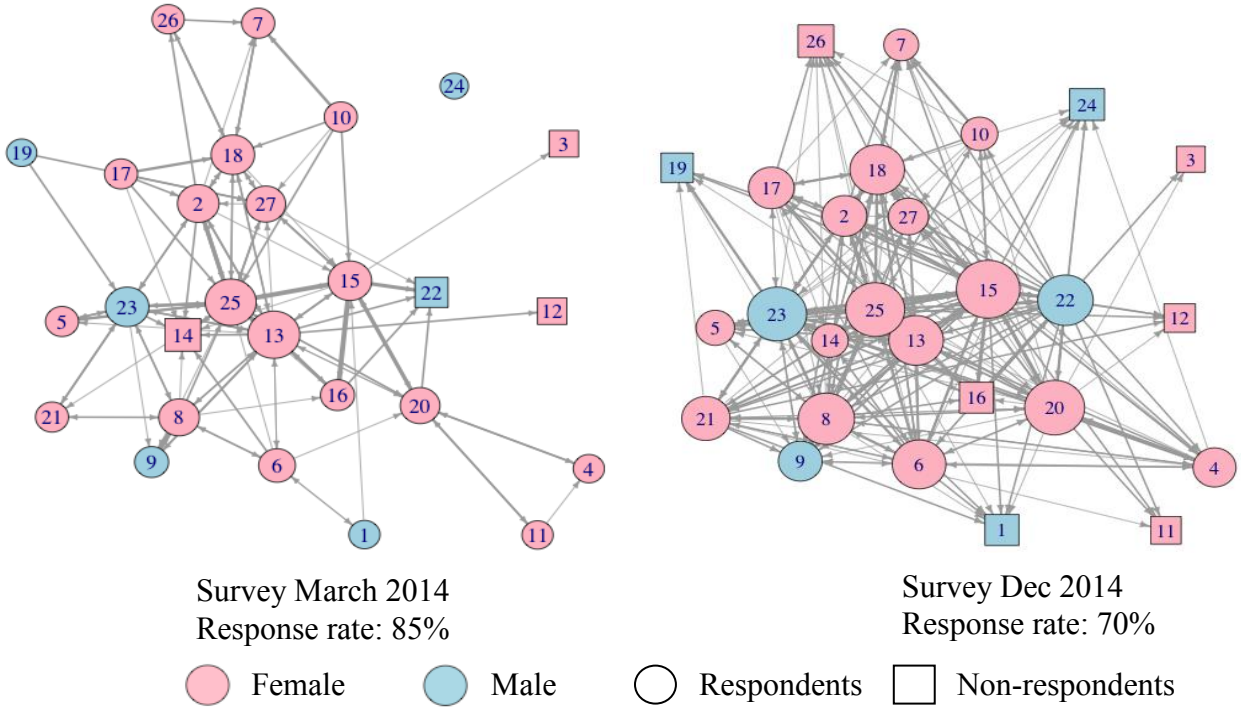
The PA SC participants were from the same state and some of them already connected through the Pennsylvania Association for Environmental Educators and other activities before the program. The PLC participants were from different states in the US, so few of them knew each other before the program. The CCC participants were from different states in the US and a few of them were from Canada and Mexico, and few participants knew each other before the program.

Table 7. Descriptive statistics of network measures in all programs.

Network metrics	Pennsylvania State Consortium		Project-based Online Learning Community		Community Climate Change Fellowship	
	Pre	Post	Pre	Post	Pre	Post
Nodes	27	27	43	43	26	26
Edges	112	468	9	72	10	327
Group density	.16	.37	.01	.04	.02	.50
In/out degree mean	4.15	9.63	.21	1.67	.39	12.00
In-degree median	3	9	0	2	0	12
In-degree range	0-13	2-16	0-2	0-5	0-3	10-18
Out-degree median	2	7	0	1	0	8.5
Out-degree range	0-15	0-26	0-2	0-10	0-2	0-25
Closeness mean	.39	.49	.01	.09	.03	.70
Closeness median	.43	.57	0	.02	0	.60
Closeness range	0-.71	0-1	0-.06	0-.27	0-.13	0-1
Betweenness mean	24.58	13.21	.13	13.26	1.00	16.40
Betweenness median	.73	5.73	0	0	0	7.09
Betweenness range	0-174.00	0-66.56	0-2.5	0-88.50	0-8.00	0-55.66

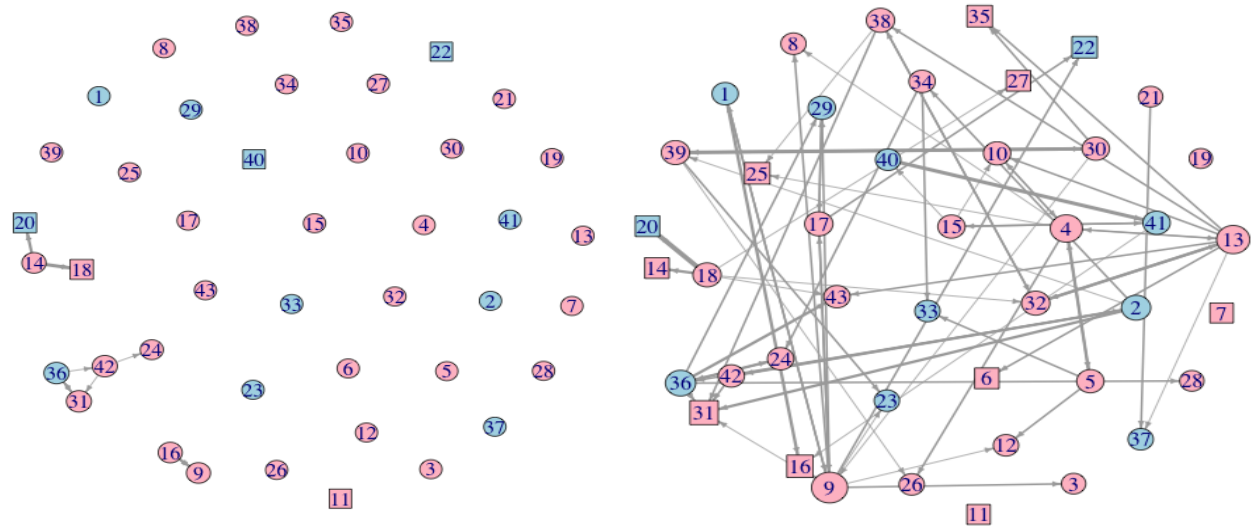
The closeness centrality measures the distance of each participant to all other participants (Table 7). The mean values of closeness centrality increased across all three programs indicating that participants had closer distance among each other in each program. Further, the betweenness centrality means the number of shortest paths going through each participant. The mean values of betweenness centrality decreased in the PA SC indicating that the PA SC participants no longer relied on just a few participants to pass through for information. The mean values of betweenness centrality increased in the PLC and CCC, indicating that more participants became

brokers in the network to help connect other participants.



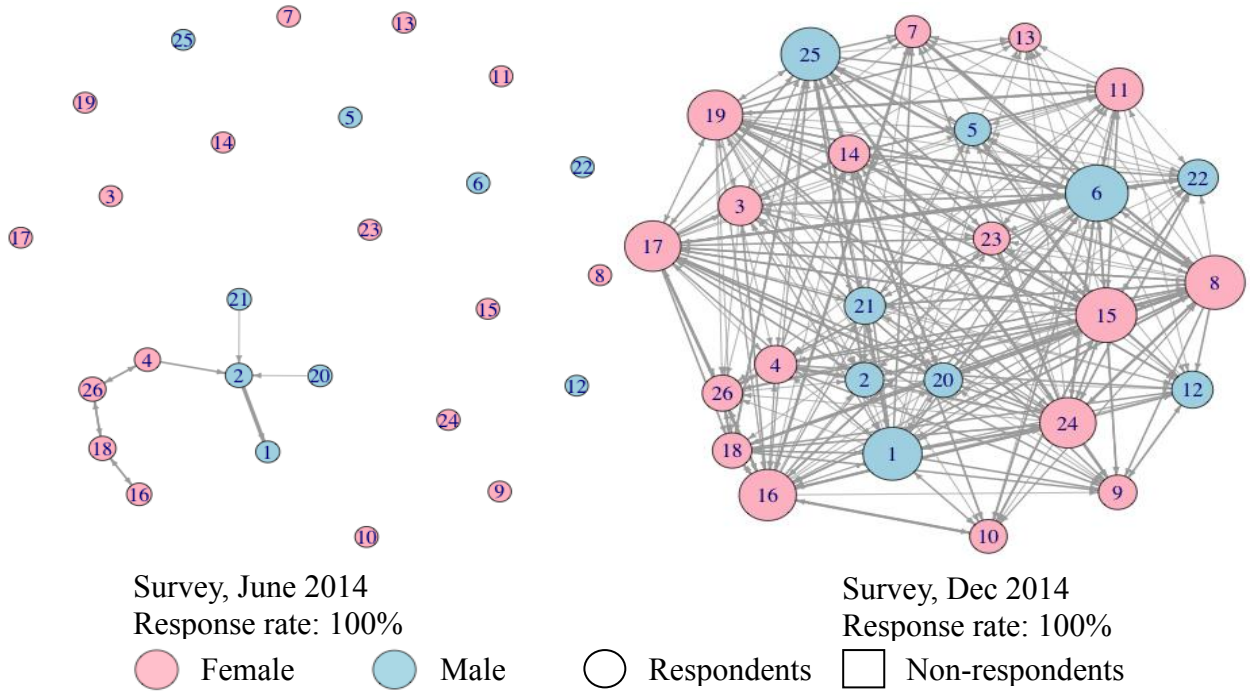
The size of the node indicates degree centrality and the width of the tie indicates strength.

Figure 2. Individual networks of Pennsylvania State Consortium before and after the professional development activities.



The size of the node indicates degree centrality and the width of the tie indicates strength.

Figure 3. Individual networks of Project-based Online Learning Community before and after the professional development activities.



The size of the node indicates degree centrality and the width of the tie indicates strength.

Figure 4. Individual networks of Community Climate Change Fellowship before and after the professional development activities.

ERGMs results

ERGMs results showed the coefficients associated with each parameter, as well as the standard error for each professional development program (Table 8). Each ERGM predicts the presence of network ties in each group with estimates indicating the importance of each parameter to the presence of a tie (Lusher, Koskinen, & Robins, 2012). I chose the models with the best goodness-of-fit, which were indicated by the lowest value for Akaike information criterion (AIC) and Bayesian information criterion (BIC).

In terms of structural mechanisms, reciprocity had a significant positive effect on formation of network ties after the professional development activities ($b = 2.981$, $p < .001$) only in PLC, indicating that the connections in the PLC tend to be mutual. In other words, a PLC participant was likely to reach out to another participant if that same participant contacted him or her. Further, in-degree centrality (popularity) had a significant negative effect on tie formation in the PLC and CCC ($b = –1.072$, $p < .05$; $b = –1.695$, $p < .001$, respectively) indicating that participants have a similar level of popularity and the networks were not centralized on in-degree. Finally, transitivity had a significant positive effect ($b = .305$, $p < .001$) only in the PLC indicating that the connections tend to be more balanced in the PLC. In other words, if participant A connected to B, and B connected to C, it was likely that A also connected to C.

Table 8. ERGMs results.

	PA	PLC	CCC
Edges	-4.690 (.502)***	-2.542 (1.149)***	6.212 (1.940)**
Structural mechanisms			
Reciprocity	-	2.981 (.763)***	-
Popularity	-	–1.072 (.478)*	–1.695 (.406)***
Transitive triples	-	.305 (.085)***	-
Assortative mechanisms			
Webinar attendance	.559 (.091)***		
Meeting attendance	.433 (.125)***		
Meeting network	.984 (.300)***		
Pre-program network	2.291 (.426)***		
Facebook Post		– .059 (.021)**	-
Facebook comments to participants		.053 (.013)***	-
Facebook comments from participants		-	– .046 (.015)**
Facebook comments to facilitators		-	.856 (.188)***
Facebook comments from facilitators		-	.905 (.173)***
Facebook network		.796 (.415)#	-
EBook co-authorship		4.265 (.624)***	-
Gender Male	1.440 (.251)***	-	-
Homophily Race	-	.780 (.290)**	-
Race-White	-	– .554 (.243)*	.848 (.177)***
Work Year >=10 years		.645 (.214)**	– .954 (.159)***
AIC	445.5	387.9	794
BIC	470.7	455.6	825.3

****p < .001; **p< .01; *p< .05; # p* < .1; - no significance

In the PA SC, webinar attendance had a significant positive effect on likelihood of forming a tie ($b = .559$, $p < .001$), which means participants who attend more webinars were more likely to form a tie with other participants. Similarly, meeting attendance had a significant positive effect ($b = .433$, $p < .001$) indicating that participants who attended more face-to-face meetings were more likely to form a tie with other participants. Webinar network showed no significant effect, while meeting network showed a significant positive effect ($b = .984$, $p < .001$) indicating that any two participants who attended a same face-to-face meeting were more likely to form a tie between them. Further, the pre-program network had a significant positive effect ($b = 2.291$, $p < .001$) indicating that participants who already connected to each other were more likely to keep connecting. Finally, gender male had a significant positive effect ($b = 1.440$, $p < .001$) meaning that male participants were more likely to connect to other participants in PA State Consortium.

In PLC, the total number of Facebook posts had a significant negative effect on the likelihood of forming a network tie ($b = -.059$, $p < .01$) meaning that participants who posted more on Facebook were less likely to connect with other participants. However, the number of Facebook comments to other participants had a significant positive effect ($b = .053$, $p < .001$) indicating that participants who made more comments to others were more likely to connect with other participants. Further, Facebook communication network had a marginally significant positive effect ($b = .796$, $p < .1$) indicating that two participants who communicated on Facebook were more likely to connect to each other. The eBook co-authorship network had a significant positive effect ($b = .053$, $p < .001$) meaning that two participants who co-authored on a same chapter increased the likelihood of connecting to each other. Finally, white race had a significant negative effect ($b = -.554$, $p < .05$) meaning that white participants were less likely to form a tie

with other participants. The work year had a significant positive effect ($b = .645$, $p < .01$) indicating that participants with more than 10 years working experience in environmental education were more likely to connect to other participants.

In CCC, total number of Facebook post and comments to other participants had no effects on tie formation, whereas Facebook comments from participants had a significant negative effect ($b = -.046$, $p < .01$) indicating that participants who received more comments from other participants were less likely to form a tie with other participants. In addition, both Facebook comments to and from facilitators had significant positive effects ($b = .856$, $p < .01$; $b = .905$, $p < .001$, respectively) indicating that participants who interacted with facilitators were more likely to form a tie with other participants. Further, white race had a significant positive effect ($b = .848$, $p < .001$) meaning that white participants were more likely to form a tie with other participants. Also work year had a significant negative effect ($b = -.954$, $p < .001$) indicating that participants with more than 10 years working experience in environmental education were less likely to connect to other participants.

Finally, the proximity mechanisms by geographic distance showed no significant effects across three programs suggesting that distance between participants had no impact on the likelihoods of these participants networking with each other in all three groups.

Interviews and reports

The results of the interviews and report analysis help us to understand how networks were formed through different professional development activities in each program.

One initial PA SC co-leader talked about how they started the program to engage participants from different regions:

> *Even when I was writing the grant, I wanted to make sure that people across the state of Pennsylvania were involved…The Pennsylvania Association of Environmental Educators*

is divided and we have six regional directors. I was really trying to get people in from all the regions involved. (PA SC-RR)

This co-leader continued explaining how participants developed connections among each other through face-to-face meetings. Although some participants dropped out during the program, the remaining consortium members worked well together and wanted to continue working even after the program ended.

The very first meeting, you bring in 23 people together. Some of them knew each other but the majority did not. You are like are they going to ... How's this going to work? ...And people just came in and just started talking to each other as if they have been best friends for their whole lives. I heard people saying oh yeah, I will let you know what I have about this, and so on that personal basis. I have seen that. There are people that have fallen away. I mean that's to be expected in anything that they found themselves too busy or whatever. That we don't have the whole group that we started out with. I think we've done pretty well and how many we have. And I think that our leadership team has been sticking with it and being so strong and wanting to have this continues to happen. (PA SC-RR)

A participant in the PA SC explained how her network was strengthened through the PA SC professional development activities:

I think it has certainly strengthened my relationship or at least continued to strengthen my relationships particularly with the people that are in closest proximity to me that I would have you know that I would more likely collaborate with on a project or a program. But I also in terms of the statewide network I see value in that as well. I think I this year got a lot more out of the PAEE conference, just like knowing more of the people from other parts of the state. (PA SC-KH)

Another PA SC participant mentioned that his networks also expanded beyond the PA SC:

It's actually added more partners to our existing coalition and it allowed us to increase our own organization's awareness and outreach on a broader scale to a not only a regional level or in a more localized level in some of these other counties, but it's actually helped us on a national level because the NAAEE (North American Association for Environmental Education) recognized the work that we've done, my organization has done it within the consortium, and had allowed me to make a presentation for others to see on a national level, and to receive a scholarship to be able to attend, and make that kind of presentation as one of so many only a few of these type of nonprofit sector make those presentations. That was an honor in itself, but that allows us to become a part of a national network to serve as a shining example of what a small nonprofit can do (PA-RH).

A PLC participant mentioned how she connected to other participants through Facebook

interaction, which lead to an initial conversation and collaboration on writing a chapter together.

> *You know because she saw that we had similar interests based on the things that we were posting in the group, and then he [another participant] found his way to me based on my postings things about global climate change and … that we had an initial conversation. And then [another participant] reached out to me because … she was very hands-on and directly involved with the Seattle Parks Recreation that she has some very on the ground practical experience of how tools that would be appropriate for covering the topic like the environmental justice. So I think in the short run we all came together very organically just through an initial connection and an initial connection making another initial connection and so forth and so on. We had not worked together previously. (PLC-DN)*

Although connecting online provided diverse ideas for participants, participants would like building local connections for further collaboration. A participant explained:

> *I mean the distance is a little bit of a barrier… And it's good to collaborate we know, but again because I'm part of a bigger machine…I wonder who we could talk to locally to make the impact because locally is where we need to concentrate our efforts and I think that's part of why I'm not as readily reaching out as well. (PLC-TS)*

From CCC reports, participants mentioned that the CCC created opportunities for them to develop networks among each other. A participant explained how the first workshop helped her connect to other participants, and how she continued networking with some of the participants:

> *The weeklong training in West Virginia helped me to hear about others' projects and to better-clarify my own, as well as to network with and learn from some of the most amazing and positive people I know. … Since then, there are three or four fellows with whom I have remained in consistent contact either to provide them with resources, share CC101 PowerPoint (climate change) and information, or to get their feedback on what I am doing. For me, the network of this fellowship is definitely its greatest strength. (CCC-JH)*

Participants also interacted on Facebook, through which participants connected to each other and shared resources.

> *It has been very helpful and supportive to have a network of other environmental educators on the same path in many different locations, working on meaningful projects in each of their communities. Specifically, [a participant] has been very helpful through the number of resources she has shared over our Facebook community. (CCC-KS)*

For those who already knew each other before, the CCC helped them strengthen their

relationship. One of them explained how their local partnership was reinforced through the program:

> *It has also allowed and inspired me to reinforce existing partnerships and create new ones, in particular with fellow [name]'s [name] Foundation and an NGO we work with based in San Diego. (CCC-LM)*

A participant explained how networking through CCC would lead to project collaboration and expanding networks beyond CCC.

> *Through my contact with another EE Capacity Fellow, I am planning to work with the Environmental Justice class at [name] High School in New Haven this spring. (CCC-JD)*

Online interactions helped participants to connect, but may not be sufficient to deepen the relationship. A participant showed her interest to explore ways to continue networking and sharing with others:

> *I think I am also feeling a little challenged how to make some mutual support "Fellowship friends" across distance, etc. The sporadic check-ins and Facebook themselves are not sufficient to deepen those mutual support connections…I would love to know if there are other things I could be sharing that would help support others' work as well. (CCC-MH)*

Through connecting with each other, the CCC participants expanded their networks beyond the program.

> *Prior to the fellowship, I'd not networked with other co-designers in other cities in Canada. After the leadership workshop, I knew that I must set up a meeting with other co-designers so we may create a national strategy for our organization. (CCC-SC)*

Discussion

The results from this study support the idea that professional development programs that attempt to create professional learning communities can impact the formation of professional networks among environmental educators. Across all three programs, the networks became denser indicating that participants built networks for exchanging ideas and practices in environmental education through the professional development activities. The density and

average degree centrality of the CCC was the highest among three groups, which may be attributed to the fact that the CCC participants engaged in both face-to-face and online interactions, which enabled them develop more connections relative to the PA SC and PLC participants. Although participants in the PA SC had five, one-day face-to-face meetings, not everyone went to all the meetings. Also very few PA SC participants were active on Facebook. In PLC, the interactions mostly relied on Facebook interactions. It is also possible that the density decreased as the group size became larger (Aviv et al., 2008). The PLC with 43 participants had relative lower density (.04) than the PA SC (.37) with 27 participants and the CCC (.50) with 26 participants.

The results of the ERGM analysis showed the significant negative effect of popularity on network formation in both the PLC and CCC, which is in line with findings from previous studies on teachers' advice networks (Siciliano, 2015) and teachers' online communication networks in online courses (Kellogg et al., 2014). Lusher et al. (2012) suggested that when participants had similar levels of popularity, the network is not centralized on in-degree. In other words, a participant connecting to another participant would not depend on how popular another participant was. Further, the significant positive effect of transitivity on network formation in the PLC suggested that a participant tended to connect to another participant who shared a mutual contact only in the online only program. Aviv et al. (2005) also found significant transitivity in one online learning network, in which 19 participants collaborated on a writing proposal as a team; this goal-directed design of the team network required its participants to reach consensus, which led to the balance mechanism of tie formation. Similarly in this study, participants in the PLC collaborated in small groups to write, which might lead participants to form transitive triangles to reach a balanced status. The result of co-authorship increasing likelihood of tie

formation in the PLC showed that participants collaborating in a group were more likely to form connections between each other. The results suggest that project-based collaboration work help participants to develop stable connections.

Participating in face-to-face activities had a significant positive relationship with formation of professional networks. In the PA SC, the result that going to the same face-to-face meeting increased the likelihood of participants connecting to each other, is consistent with findings from previous research that showed participating in the same meetings increased the likelihood that teachers sought advice from one another (Penuel et al., 2010). In an online graduate course, Haythornthwaite (2001) also found that a short face-to-face interaction session had a catalytic effect on social and emotional exchanges among students. In the CCC, although there were only two face-to-face events including a weeklong workshop and a conference, participants mentioned the importance of these activities in shaping their networks. In the PLC without any face-to-face interactions, the network among participants was relatively loose. Participants mentioned challenges of building consensus on writing without seeing each other. One participant also indicated that finding a local partner was important for long-term collaboration. The results suggest offering face-to-face interactions for participants to build connections and further strengthen connections.

Facebook interaction influenced network formation in both the PLC and CCC groups, but the specific driving factors varied in these two groups. Participants who posted more on Facebook were less likely to form connections with others, while participants who commented more were more likely to form connections in the PLC. Some participants may share information and resources online, but not engage in discussion. Those who made comments paid attention to other participants' posts and engaged in interaction, which led to high likelihood of forming

networks with others. However posting and commenting online showed no significant impacts on tie formation in the CCC. A possible explanation is that participants relied mostly on online interaction to learn about each other in the PLC, while participants in the CCC could learn about each other through multiple ways including face-to-face meetings. In addition, the results that participants' comments to and from facilitators increased the likelihood of network formation between participants in the CCC supports the finding by de Laat, Lally, Lipponen, and Simons (2007b) and Y. Li et al. (2014) that instructors or facilitators of online learning communities play a key role in promoting networking among participants. However, interacting with facilitators on Facebook in the PLC showed no effect on tie formation among participants; one explanation is that compared to the CCC which had multiple facilitators, the PLC had one facilitator who coordinated the group-writing project through emails rather than interacting with participants on Facebook.

Further, the results of gender, race and work year had different impact on network formation. First, male participants were more likely to connect to other participants in the PA SC (2 males, 15 females). In the PA SC, the professional development activities relied mostly on face-to-face meetings to form local connections. Thus the impact of gender may be more obvious than in the PLC and CCC, which relied mostly on online interactions to form connections across the country. Second, the result for homophily by race indicated a significant positive effect in the PLC, meaning that participants with the same race were more likely to connect with each other. In teachers' advice networks, Spillane et al. (2012) found that teachers tend to seek advice from other teachers who have same race. In the PLC, it could be that participants tended to collaborate with other participants with the same race on writing a chapter or participants with the same race had similar found common interests in a topic. Specifically, white participants were less likely to

connect with other participants in the PLC, while white participants were more likely to connect with others in the CCC. It also could be that the impact of race was more obvious in the CCC with face-to-face meetings than in the PLC without any face-to-face meetings. Third, participants with 10 or more years of working experience in environmental education increased the likelihood of connecting with other participants in the PLC, but decreased the likelihood in CCC. In an online professional development course, Y. Li et al. (2014) found that participants with fewer years of working experience in environmental education were more likely to intend to adapt environmental education ideas. Similarly, in the CCC with the goal of creating new projects, less experienced participants tended to connect to other participants for ideas and resources that could be applied to their new projects. However, the PLC with the goal of co-authoring eBook chapters required group collaboration. Thus, more experienced participants might be more likely to reach out to other participants and coordinate collective writing. They also may have acted as editors to review other chapters and develop connections across groups.

In contrast to previous studies which showed the impact of geographic distance on network formation in face-to-face (van Duijn et al., 2003) and online settings (Kellogg et al., 2014; Yuan & Gay, 2006), the geographic distance showed no impact on network formation in this study. Similar to how the students in a MOOC from one country were more likely to communicate with students from another country (Joksimović et al., 2016), participants connected to each other across the state in the PA SC, and across the country in the PLC and CCC. For environmental educators, networking with participants from different regions or states may provide them with diverse perspectives, which may foster innovation in practice (Biggs et al., 2010; Mulgan et al., 2007). However, in terms of long-term collaborations, participants may prefer local connections. Participants mentioned in the interviews that they met with or would

like to meet with other participants close by.

Finally, the results showed that SNA was a useful means to understand educators' interactions through examining network structure and formation mechanisms in professional learning communities. Previous studies used the community of practice framework more generally to understand the importance of teachers' learning in social contexts (Akerson et al., 2009; Bannister, 2015). This study conducted social network analysis to examine specifically how educators interacted with each other for the exchange of ideas and practices, which helps us understand mutual engagement in communities of practice (Wenger, 1998). Further, previous studies mostly relied on descriptive analysis when using SNA to examine teachers' interactions through face-to-face (Penuel et al., 2009) and online activities (Sing & Khine, 2006). The results of this study add to the literature on network formation and structure in educator professional development by conducting ERGMs that predict network tie formation. Finally, adding to research that used network models to explore formation of advice networks among teachers (Moolenaar, Daly, Sleegers, et al., 2014; Siciliano, 2015; Spillane et al., 2015) and online communication networks in online courses designed for teacher professional development (Kellogg et al., 2014), this study explored how online communication networks as part of professional development activities impacted participants' professional network formation.

Limitations

The groups examined in this study had relatively small numbers of participants. Although using a small sample size is not unusual in social network research (Wasserman & Faust, 1994), it is hard to generalize findings to broader settings. Also the relatively low response rates in the PA SC and PLC resulted in missing ties in the networks, which impacted network measures. Further, the post-surveys were conducted right after the professional development programs. I

did not conduct a follow-up surveys several months later to check if participants kept connecting after the programs. Future research should conduct longitudinal studies in which networks will be measured overtime. In addition, I counted the number of Facebook posts and comments, but I did not check the content of the posts and comments. Also the Facebook communication network only captured poster and commenter interaction without commenter and commenter interaction. These shortcomings could be addressed through content analysis of participants' posts and comments. Finally, I was not able to capture all the participant interactions through other communication means such as emails and phone calls. I suggest adding a question to social network surveys to ask how participants contact each other.

Conclusion

The findings from this study show that professional development activities were associated with the development of new networks, which suggests the need for professional development programs to bring together diverse participants across regions and separate the well-connected participants in separate groups if a goal is for participants to exchange ideas, experience, and other resources (Penuel et al., 2012; Roling & Wagemakers, 2000). Such professional development activities may provide opportunities for well-connected participants to develop new connections with participants outside of their original group, and to act as brokers to connect multiple groups and foster information exchange. In addition, participating in professional development activities such as face-to-face meetings, webinars, and Facebook discussions played a role in developing ties among participants.

In addition, the results from this study suggest implications for future professional development programs. In particular, the fact that participants in the CCC who interacted with program facilitators tended to connect to other participants, and participants in the PLC who

posted more on Facebook were less likely to connect to other participants, suggests a role for program facilitators in engaging participants in discussion with other participants, including through online platforms such as Facebook. In addition, co-authoring an eBook chapter in the PLC provided a chance for participants to develop professional networks to exchange ideas in depth, which suggests including collaborative projects for future professional development programs.

Finally, for researchers, the results leave open questions about the impact of professional networks on professional practice (Akerson et al., 2009; Duncan-Howell, 2010) and innovation (Granovetter, 1973). For example, what kinds of shared information and resources through networking in communities of practice contribute to innovative practice? How do network position and structure impact innovation in environmental education practice? These questions will be taken up in Chapter 4.

CHAPTER 3

PRACTICE CHANGE IN ENVIRONMENTAL EDUCATION

Abstract: This study investigates how environmental educators change their practice through participation in online and face-to-face professional development activities in three programs. Drawing from practice theory, I measured elements of environmental education practice including goals, audiences, settings, activities, resources and ideas. The results showed that participants have incorporated new resources and ideas into their practice across all three programs. However, changes in the other practice elements varied among programs. The study suggests that practice theory can be used to inform studies of outcomes of professional development programs and examine environmental education practice.

Key words: practice theory, practice change, professional development, and environmental education

Introduction

Nearly thirty years ago, UNESCO (1990) identified the preparation of environmentally literate teachers as a top priority for improving environmental education. In 1992, the United States (US) Environmental Protection Agency (EPA) established the North American Environmental Education Training Program, with a goal to offer professional development and strengthen the field of environmental education. The program also has developed a series of guidelines for excellence and certificate and accreditation programs (NAAEE, 2010). From 2011 to 2016, as the fifth phase of US EPA's program, Cornell University conducted Expanding Capacity in Environmental Education (EECapacity). Through partnerships with the government, university, private, and non-profit sectors, EECapacity has created communities of practice

where environmental education and related professionals exchange ideas and resources through face-to-face workshops and online courses. The goal of these professional development activities is to foster networking that leads to innovative practices. In addition to the EPA program, universities, zoos and aquaria, national programs like Project Learning Tree, and other actors provide resources and trainings for environmental educators. Reflecting a growing international interest in professional development and resources, the Taiwanese and US EPA launched the Global Environmental Education Partnership in 2014. Given the growth in training programs, knowing the effectiveness and outcomes of environmental education professional development programs is important.

Research on the outcomes of professional development programs in environmental education has focused on educators' confidence and knowledge and skills acquisition. For example, studies found significant positive changes in levels of knowledge, understanding and confidence (Dyment et al., 2013; George, Clewett, Birch, Wright, & Allen, 2009). Other studies showed teachers improved their environmental attitudes and behavior (Álvarez-García, Sureda-Negre, & Comas-Forgas, 2015; Yavetz, Goldman, & Pe'er, 2014) and enhanced self-efficacy and outcome expectancy, i.e., the performance level one expects to achieve (Moseley, Huss, & Utley, 2010). O'Donoghue and Russo (2004) point out that professional development of environmental educators addresses not only knowledge and skills acquisition, but also helps educators adapt ideas and resources to improve their practice, and suggested that these latter areas were additional avenues for research.

Studies of the effectiveness of professional development programs also have examined teaching practice, by asking teachers whether they adapted what they learned in their classroom teaching (Paul & Volk, 2002; Sondergeld, Milner, & Rop, 2014). Working in non-formal settings,

McConnell and Monroe (2012) examined whether 4-H volunteers who had participated in online professional development intended to adapt what they learned in their practice and Bainer, Cantrell, and Barron (2000) investigated how non-formal educators applied what they have learned from elementary school teachers to their practice. However, we are aware of no studies that have rigorously defined change in practice as a result of professional development in environmental education.

Practice theory, which focuses on professional, consumer, and other practices and how practices emerge, evolve, and sustain themselves (Reckwitz, 2002; Schatzki, 2001), provides a framework to examine environmental education practice. Previous research has applied practice theory to conceptualize professional learning in industry (Boud & Hager, 2012; Reich, Rooney, & Boud, 2015) and teaching practice (Lampert, 2012; Pienaar & Lombard, 2010). Kemmis and Mutton (2012) applied practice theory to environmental education using cultural, discursive, social and material dimensions of practice. However, these dimensions are rather abstract and difficult to measure. To understand environmental education practice change as a result of professional development programs in depth, I draw from characteristics of environmental education such as purpose (Eames, Cowie, & Bolstad, 2008), audiences (Sondergeld et al., 2014), settings (Simmons, 1998; Torquati & Ernst, 2013) and activities (Stern, Powell, & Hill, 2013). By defining practice elements, this study provides insights into environmental education practice in a manner consistent with practice theory research in consumer (Gram-Hanssen, 2010) and stewardship (Krasny et al., 2015) studies.

To enhance our understanding of the impact of professional development programs on environmental education practice, in this study I draw on practice theory to define six practice elements (goals, audiences, settings, activities, resources and ideas). I then trace changes in these

practice elements among environmental educators participating in three professional development communities of practice: a state consortium that brought together environmental education, an online learning community that explored urban environmental education and youth development professionals, and a fellowship program focused on climate change. My specific research question is: How did environmental educators change their practice through participating in communities of practice? The results help us understand the impact of communities of practice created by professional development programs, including those with a strong social networking component (see Chapter 2), on practice change in environmental education. Further this study extends practice theory to professional development in environmental education.

Literature Review

Below I provide brief overviews of studies measuring outcomes of educator professional development and of practice theory.

Professional development

B. Bell and Gilbert (1996) proposed a model to conceptualize teacher development that incorporates three dimensions: personal, social and professional development, two of which, social development (Chapter 2) and professional development (this chapter), I consider in this dissertation. Professional development focuses on teaching skills and practices, and includes three stages from trying out new activities, to development of new ideas and practices, to continuing to develop other activities after the programs (B. Bell & Gilbert, 1996). For the purposes of my study, I define professional development as educators adapting into their practices ideas learned through interacting with program leaders, facilitators, and other educators in training programs.

Previous studies applying different models to evaluate professional development programs have acknowledged the importance of evaluating teaching practice as a result of such programs (Clarke & Hollingsworth, 2002; Desimone, 2009; Guskey, 2000). For example, Guskey's (2000) model for evaluating professional development includes five levels: participant reaction to the training, participant learning, organizational support and learning, participant use of new knowledge and skills, and student learning outcomes. This model has been widely used in the evaluation of training in K-12 school systems. However, not all the levels of the model are appropriate for assessing professional development programs for non-formal educators, which suggests a need to explore a new framework for such situations. My focus on educators' practice change through professional development activities reflects the fourth level of Guskey's (2000) model: participants' use of new knowledge and skills in practice.

Professional development in environmental education is particularly challenging due to its interdisciplinary nature, which requires synthesis of science content, social context, and pedagogical strategies (McDonald & Dominguez, 2010). Also few universities offer comprehensive environmental education coursework so that pre-service teachers have limited access to environmental education content or teaching methods (McKeown-Ice, 2000) or have to learn through science or social studies methods rather than an interdisciplinary approach (Plevyak, Bendixen-Noe, Henderson, Roth, & Wilke, 2001). In addition, environmental education is considered by school systems as supplemental to a wide range of school subjects, which makes it hard to garner schools' attention to provide environmental education professional development programs (McDonald & Dominguez, 2010). Wilke, Peyton, and Hungerford (1987) identified a list of competencies needed by effective environmental education teachers including knowledge of environmental issues and concepts, and ability to infuse environmental education

into multiple disciplines, develop new environmental education curricula, utilize effective instructional methodologies, and evaluate outcomes. Robottom (1987) proposed five principles for teacher preparation in environmental education: participatory and practice-based, enquiry-based, involves ideological critique, community-based, and collaborative.

Studies of professional development in environmental education have focused on educator confidence, knowledge and skills acquisition. For example, Dyment et al. (2013) found significant positive changes in levels of knowledge, understanding and confidence among early childhood environmental educators as a result of three professional development sessions (total 9 hours). George et al. (2009) found that a professional development climate change course helped educators improve their skills and confidence to develop climate courses or to incorporate climate in existing courses. Other studies focused specifically on pre-service teachers' environmental knowledge, attitudes and behavior (Álvarez-García et al., 2015; Boon, 2010; Tal, 2010; Yavetz et al., 2014). For example, Tal (2010) found pre-service teachers increased their environmental knowledge and awareness as a result of an introductory environmental education course, but few changed their environmental behavior. These studies considered teachers as a main focus rather than their teaching practice.

Other studies on effectiveness of professional development programs in environmental education have examined the teaching practice. For example, Paul and Volk (2002) found teachers who attended longer and more workshops were more likely to use an environmental education curriculum in the classroom. Sondergeld et al. (2014) found 95% of the teachers indicated that they would use hands-on activities that they learned from a professional development program including an eight-day training workshop and three follow-up sessions in their own classroom. In a study of online professional development training for 4-H volunteers,

McConnell and Monroe (2012) found that volunteers intended to adapt what they have learned into their practice. Bainer et al. (2000) found that through partnering with school teachers, non-formal environmental educators improved teaching practice by using resources from classroom in their practice and adjusting teaching styles. Y. Li et al. (2014) also found that environmental educators already adapted or intended to adapt ideas into their practice as a result of an online course. In short, these studies examined practice in general or some components of practice, but none of them have comprehensively investigated individual elements of practice in environmental education.

Practice theory

Professional learning is more than knowledge acquisition, but rather a situated learning process in practice (Gherardi, 2000), which is social, material, embodied, and emerging (Reich, Rooney, & Boud, 2015). An understanding of practice theory in professional learning shifts the focus from the attributes of the individual (knowledge, skills and attitudes) to the attributes of the practice (interactions, opportunities, challenges) (Reich, Rooney, Gardner, et al., 2015). Practice theory may be applied to examine professional learning among teachers as teaching practice is a key component of professional development (Guskey, 2000).

As a type of social and cultural theory, practice theory emphasizes analyzing the practice itself and offers a middle level between individual agency and institutional structures (Reckwitz, 2002). Reckwitz (2002) defined a practice as "a routinized type of behavior which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (p. 149). "A practice is a social phenomenon in the sense that it embraces multiple people. The activities that compose it,

moreover, are organized (Schatzki, 2012, p. 13).

Researchers have used different descriptions of elements to construct a practice. For example, Reckwitz (2002) focused on elements including body, mind, things, knowledge, discourse, structure/process, and the agent. Shove and Pantzar (2005) used three elements -- materials, meanings and competence -- to explain the emergence of a practice. Warde (2005) proposed three elements -- understanding, procedures and engagement -- and suggested ways to examine connections and interactions between elements. Higginson et al. (2015) applied social network analysis to visualize and interpret the relationships of practice elements. The elements of practice vary depending on different contexts.

Practice theory has been used widely in organizational studies (Brown & Duguid, 2001; Feldman & Orlikowski, 2011; Lounsbury & Crumley, 2007; Nicolini, Gherardi, & Yanow, 2003) and research on consumer behaviors (Gram-Hanssen, 2010; Halkier, Katz-Gerro, & Martens, 2011; Warde, 2005). For example, Gram-Hanssen (2010) used the elements of practice -- technology, everyday life routines, knowledge and motivation -- to examine energy consumption behavior, and found that change of behavior varied across facilities depending on differences in practice elements. Recently, practice theory has been applied to study environmental behaviors. For example, Hargreaves (2011) applied practice theory to understand how environmental practice was formed and sustained, and found that a company reduced waste and electricity use, which might be because the employees formed new interactions, identities and rules as a result of an environmental behavior change initiative. Further, Krasny et al. (2015) used practice elements -- competencies, meanings, and physical resource -- to examine how civic ecology practices emerge and expand.

Scholars also have applied practice theory to studies on the emergence of innovations.

For example, Seyfang and Haxeltine (2012) used practice theory to propose a process for the generation of grassroots innovations in civil society. Taking Nordic walking as an example, Shove and Pantzar (2005) suggest that innovation emerges through novel integration of materials, meanings and competence. They describe innovation as a continuous on-going dynamic process that involves changing combinations of symbolic and material elements and competence (Pantzar & Shove, 2010).

Other research has viewed professional development in industry and government through the lens of practice theory (Boud & Hager, 2012) in engineering (Reich, Rooney, Gardner, et al., 2015; Rooney et al., 2012), human relations (Chudzikowski & Mayrhofer, 2011), leadership (Bjørkeng, Clegg, & Pitsis, 2009; Carroll, Levy, & Richmond, 2008), and policing and medicine (Lindberg & Rantatalo, 2014). For example, Rooney et al. (2012) used practice theory to conceptualize professional learning processes in engineers' workplaces; these processes included participation in practice, construction of knowledge, and becoming professionals. Each of these studies examined different elements of practice in different contexts, which suggested to me the potential for conceptualizing environmental education practice based on its elements in order to understand practice in depth and measure change of practice.

Several scholars invoked practice theory as a framework for studying professional development of teachers. Lampert (2012) suggested regarding teaching as a practice and that professional development should link the improvement of teaching with the improvement of teachers. Pienaar and Lombard (2010) conducted self-reflective action enquiry to explore educational values and improve teaching practice. Bacevich (2010) identified four key characteristics of classroom teaching practice – active, involves understanding, social, and gains meaning in context – by analyzing pre-service teachers' video records. Ball and Cohen (1999)

proposed a "practice-focused" theory of teacher learning that makes practice the focus of professional development activities. However, none of these studies specifically mentioned how practice theory can help define practice elements or discussed their results within the context of other studies of practice theory.

I suggest that practice theory provides a framework to examine environmental education practice in both formal and non-formal settings. Kemmis and Mutton (2012) first applied practice theory in an environmental education context and used saying, doing and relating to investigate cultural, discursive, social and material aspects of environmental education initiatives. These elements and the ones proposed by researchers in different contexts mentioned above are conceptual. Inspired by the idea of using elements to construct practice and informed by environmental education literature and program design, I propose to use six applied elements of environmental education practice: goals, audiences, settings, activities, resources and ideas. Rather than broader elements from practice theory literature, these proposed elements are applied and more easily measured, and fall under or overlap with different characteristics of environmental education practice. For example, the element *goals* is in line with purposes of teachers' environmental education programs, which is one of environmental education characteristics examined by Eames et al. (2008) in formal school settings. The elements *audiences* and *settings* respectively correspond to making education relevant to students and making use of the outdoors, which are identified as core characteristics of an effective environmental education practice (Sondergeld et al., 2014). Other researchers also identify the importance of settings in environmental education practice (Simmons, 1998; Torquati & Ernst, 2013). Hogan (2002) mentions "the activity settings in which students become environmentally sensitized serve as more than locales for developing the knowledge, skills, and attitudes that are

typically regarded as key elements of environmental literacy" (p.414). The elements *activities* reflects program characteristics such as investigation, hands-on observation and discovery, cooperative learning, and play-based learning, which had positive relationships with environmental education outcomes (Stern et al., 2013). The element *resources* is discussed by Ashmann and Franzen (2015) specifically focusing on three kinds of resources -- material, human, and social -- that can work together to effectively prepare educators in environmental education. The element *ideas* is examined in Y. Li et al. (2014), who found that environmental educators adapted or intended to adapt learned ideas from an online professional development course into their practice.

Methods

In this study, I investigated environmental educators' practice change as a result of EECapacity professional development programs. I used a mixed methods research approach (Creswell, 2013) to measure the change of practice elements in three cases. First, I conducted surveys to examine whether or not each environmental educator's practice added new goals, involved new types of audiences, expanded to new settings, developed new educational activities, and used new resources and ideas. Then to get a better understanding of how and why participants changed their practice, I conducted semi-structured interviews and analyzed participants' project reports. Qualitative methods are appropriate to get richer information about practice change (Bogdan & Biklen, 2007; Denzin & Lincoln, 2005).

Participants and program intervention

Participants and program intervention are described in Chapter 1: Introduction.

Practice surveys

To measure practice change in environmental education, I conducted a retrospective survey with participants in the PA SC after the professional development activities to capture their practices before and after the professional development activities (Appendix 3), and a practice survey with the PLC and CCC participants in the beginning and after the professional development activities (Appendix 4 and 5). I used the online survey tool Qualtrics to design the surveys and sent the survey links through email.

In the surveys, I used check box, open-ended, and Likert scale questions to measure practice elements. The survey questions included the following definitions:

- *Goals:* whether or not the practice adds new goals (e.g., know about nature, develop skills, and connect with others)
- *Audiences:* whether or not the practice involves new types of audiences (e.g., age groups, race and ethnicities)
- *Settings:* whether or not the practice expands to new settings (e.g., classrooms, community gardens, and parks)
- *Activities:* whether or not the practice develops new pedagogical strategies or teaching methods.
- *Resources:* whether or not the practice uses new resources (e.g., curricula, lesson plans, videos, fact sheets).
- *Ideas*: whether or not the practice adopted new ideas.

Although researchers may not consider ideas as a practice element, I include it here because it relates to network change (see chapter 2 and 4) and may influence practice.

In check box questions, educators were asked to choose from a list of goals, race and

ethnicity categories, age groups, and activities. Race/ethnicity was included because the field of environmental education has long sought to promote diversity, inclusion and equity. In my study, the PA SC was designed specifically to increase race/ethnic diversity of environmental education program audiences, and the PLC and CCC participants also aimed to engage diverse audiences. The list of race and ethnicity categories (African American/Black, Asian/Pacific Islander, Native American/First Nations, Hispanic/Latino, White (Non-Hispanic), and other) was adapted from the US Consensus Bureau.

I used an open-ended question to ask educators to describe the resources they used. Finally, I used Likert scale questions to examine the extent to which educators changed each practice element on a scale of 1-5 (1: Not at all, 2: A little bit, 3: Some, 4: A lot, 5: Totally). For the Likert scale questions, I present the responses for each scale category and the mean scores for each item.

Linear mixed-effects models

I used linear mixed-effects models to examine the practice elements based on check box survey questions with a random intercept of participants and fixed effect of time of survey (before versus after)[2], controlling for participants' demographics including gender and race in the PA SC, and gender, race, age, and work year in the PLC and CCC. The linear mixed-effects model was appropriate for my research for two reasons. First, my research question was to understand the change of practice elements after the professional development programs. This model could be used to examine the difference between time of survey (before and after) by

[2] I used *before* and *after* to indicate if the question asked about each practice element before or after the program rather than the time when the survey was conducted. For the PA SC, I conducted a retrospective survey after the professional development activities to capture their practices before and after the professional development activities. For the PLC and CCC, I conducted a practice survey in the beginning and after the professional development activities.

controlling for educators' demographics. Thus it helped answer my research question about the change of practice elements from before to after the programs. Second, my data involved repeated measures, which violated the independent and identically distributed assumptions inherent to regular linear regression. In short, the linear mixed-effects model with a random intercept of participants and a fixed effect of survey (before and after) addresses the issue of repeated measures.

The dependent variable was the number of choices for each practice element in each model. I counted the number of choices for each element from the check box questions before and after the professional development activities. The independent variable was time of survey, which was coded as binary variable (before and after). In the PA SC, the control variables, gender and race, were coded as binary variables (female and male, white and non-white). In the PLC and CCC, educators also reported their age and work year. Specifically in the PLC, educator age was dichotomized by the mean age (under 45 years old, and 45 years old or above), and work year was dichotomized by the mean work year (less than 10 years, and equal or more than 10 years). In the CCC, age was dichotomized by the mean age (under 40 years old, and 40 years old or above), and work year was dichotomized by the mean work year (less than 10 years, and equal or more than 10 years).

Interviews and Reports

To gain a deeper understanding of how participants changed their practice, I conducted semi-structured interviews with 7 participants from the PLC, and 5 participants from the PA SC after the professional development activities (see Appendix 2: Semi-structured interview guide). Two participants interviewed were in both the PLC and PA SC. Based on their surveys, I chose participants who changed practice elements a lot, some, and not at all. If the participants'

practice changed as a result of the professional development activities, they would be asked how each element of practice (goals, audiences, settings, activities, resources and ideas) changed. If the participants did not indicate any changes in practice, they would be asked why. I transcribed the interviews and coded the transcripts in Excel using predetermined codes based on the practice elements (goals, audiences, settings, activities, resources and ideas) (Saldaña, 2009).

Because the project external evaluator had interviewed 12 participants from CCC, I was asked not to conduct further interviews with this group. However, I coded their mid-term and final project reports in which they described their climate change education projects and reflected on how the training program helped them develop their projects.

Validity

Content validity was addressed by reviewing previous research on practice theory and environmental education programs, and by asking expert opinions to develop the list of elements. Convergent validity was addressed by comparing the results from both surveys and interviews in the PA SC and PLC, and from both surveys and reports in the CCC (Jick, 1979).

Results

I report results from the descriptive analysis and linear mixed-effects models based on surveys, following which I report results from interviews and reports. Across all three programs, participants incorporated new resources and ideas into their practice as indicated from Likert scale questions. The change in other practice elements varied in the different programs. The results from the check box questions showed the number of goals only significantly changed in the PA SC, the number of educational activities changed in both the PLC and CCC, and the number of audience age groups and settings significantly changed in the CCC.

Pennsylvania State Consortium

The PA SC created a learning community for 27 educators and community development professionals. The response rate was 62% (n=17) in the retrospective practice survey. One participant who missed a few questions on practice elements was removed from the statistical analysis.

After controlling for the participants' demographics including gender and race, the participants significantly increased the number of the goals in their practice (F (15) = 10.39, p = .006) (Table 9 and Table 10). However, the participants did not significantly change the number of their audience race and ethnicity categories (p = .669), audience age groups (p = .333), settings (p = .432) and activities (p = .261). I included interaction between time of survey and each of the control variables (educator gender and race). However they were not significant (p < .1) and thus were dropped.

Table 9. Change of practice elements based on check box questions in Pennsylvania State Consortium.

PA SC	Before/after program	Mean	SD
Number of Goals	Before	6.44	2.34
	After	7.19	2.07
Number of race/ethnicity categories	Before	3.38	1.41
	After	3.44	1.36
Number of age groups	Before	3.82	1.87
	After	3.69	1.85
Number of settings	Before	5.06	2.32
	After	5.19	2.17
Number of activities	Before	8.56	1.93
	After	8.81	1.76

Table 10. The linear mixed-effects models results in Pennsylvania State Consortium

	Number of goals			**Number of race/ethnicity categories**			**Number of age groups**		
	Den DF	F value	P value	Den DF	F value	P value	Den DF	F value	P value
Gender	13	.01	.935	13	.34	.569	13	.28	.606
Race	13	.04	.845	13	.01	.908	13	.03	.865
Time	15	10.38	.006**	15	.19	.669	15	1.00	.333
	Number of settings			**Number of activities**					
	Den DF	F value	P value	Den DF	F value	P value			
Gender	13	.02	.891	13	1.45	.250			
Race	13	1.02	.331	13	.42	.527			
Time	15	.65	.432	15	1.36	.261			

****p < .001; **p< .01; *p< .05; # p* < .1.

Note: Den DF stands for denominator degrees of freedom. In mixed effect models, the degrees of freedom for F test are approximated by using Satterthwaite approximation. So the value of degrees of freedom may vary for different factors. Time stands for time of survey (before and after).

Goals

The PA SC participants checked off program goals before and after the professional development activities including environmental knowledge and attitudes, pro-environmental behavior, mitigating environmental problems, solve social problems, urban agriculture, community development, fostering sense of place or connection to nature, and facilitating participation in urban planning. The participants also named several other goals that were not listed in the survey before and after the program, for example, reaching underserved communities and audiences, and sustainability. In addition, when asked to rate the degree to which their program goals changed on a scale of 1-5 with 1 not al all and 5 totally, the mean score of changing goals was 2.56 (Table 11).

Table 11. Degree to which participants report changing practice elements based on Likert scale survey questions in Pennsylvania State Consortium (N = 16).

	NA	Not at all	A little bit	Some	A lot	Totally	Mean	SD
Revised or added new goals	0	2	4	9	1	0	2.56	.81
Involved different or more types of audiences	2	3	3	7	1	0	2.43	.94
Expanded programs to new settings	3	4	3	5	1	0	2.23	1.01
Revised or developed new educational activities	1	4	5	4	2	0	2.27	1.03
Used new resources to inform the programs	0	1	3	7	4	1	3.06	1.00
Used ideas learned from other participants	0	0	1	9	3	3	3.50	.89

In the interview, a consortium leader who headed up an environmental restoration non-profit organization changed his program goals to focus less on solving problems and more on incorporating diversity and community development.

> *I don't think we solve the problem. What we have done was open the doors to communicate more readily and by talking with more people in more coalition partners and community learners to find out more about what the real issues are. So in that respect we have done that and you know particularly along the lines of diversity here and incorporate that topic and issue of importance into our work and the strategic plan so that helps me and said we did do that…(PA-RH)*

> *We have increased community development. I've used a lot of activities and sort of knowledge that was came through the community of learners in our meetings and webinars and face-to-face meetings to bring those practices into play within the community groups that we work with. That's built some community development that's given us more volunteers that increased our capacity to do work. It allowed my staff to become involved with other efforts that they normally would not have been involved. So to me that's capacity building…(PA-RH)*

Other interviewees did not talk about changing their goals but rather about enriching their programs. For example, a participant mentioned, "*as we are expanding our program and adding on more offerings and more options for students. I think that's what you're seeing there, but the goals and programs are always sort of the same. It's more rich I guess maybe" (PA-T).*

Audiences

Based on the Likert scale survey question, the mean score of changing audiences was 2.43 (Table 11). Two out of 16 participants chose not applicable for changing their audiences, which indicated that they might not have control over their audiences. One co-leader decreased the types of audiences because she retired during the program and switched the focus of her work. A participant who works in a non-profit providing school programs provided insight on why programs might not change audiences:

> *We partner with school groups and stuff like that. But in terms of those age groups, we don't have any specific programs that happen on a regular basis (PA-K).*

However, some educators worked to expand their programs and reach out to more diverse audiences and underserved communities. A co-leader explained:

> *Through the community of learners (PA SC) we're going after other grants and things to work with after-school programs and the low-income housing projects that are affiliated with the school districts that we're serving to get out the students in another way… So we're going back to go after more grants to target those audiences of elementary students to do more programs…that actually increases the diversity (PA-RH).*

Settings

The PA SC participants indicated different kinds of settings where they conducted practices including urban parks and other green areas, community gardens, and nature areas. Based on Likert scale survey question, the mean score of changing settings was 2.23 (Table 11). Four out of 17 respondents chose not applicable for changing their settings, which indicated that they might not have control over the settings. A participant who added botanical garden as a setting after the PA SC explained that: "we had a teacher workshop and we co-facilitate that workshop with the Parks Conservancy. So I added that … we had a workshop there (botanical garden)" (PA-T).

Activities

The PA SC participants conducted a number of educational activities, for example, walking tours or neighborhood explorations, creating or using media, using online technology, and visits to environmental facilities. Based on Likert scale survey question, the mean score of changing educational activities was 2.27 (Table 11).

A participant who added visits to environmental facilities explained:

> *I can't say for sure whether we would have done it anyway or not but we did we organized tours for us (audiences in her program) to go to see (coal mining water) treatment sites… So we went to see some green infrastructure sites as well…(PA-K)*

Through face-to-face meetings, participants not only shared the education activities they conducted in their programs, but also tried some activities at the meetings. A participant mentioned that one of these activities could be helpful for her programs. She explained that: "*we did an activity… I thought that was a really interesting activity so I might use that activity" (PA-NP)*.

Resources

We did not have a check-off box question for resources due to the fact that we would not have been able to capture all potential resources used by participants. However, the mean Likert scale response for using new resources was 3.06 (Table 11). In response to an open-ended survey question about how the resources they use for their programs changed as a result of participation in the PA SC (Appendix 3), 8 of 15 respondents reported having more resources to use by connecting to others. A participant explained, "*I now have more resources to contact and network with to obtain my program goals*. *If I am looking for a particular resource or experience for my students I know where to look*" (PA-PK). Two of them mentioned that their resources did not change, but they built more connections from which they gained resources, "*my resources*

have not changed. If people are considered a resource, my network of people has expanded. I am able to infuse new ideas and partnerships into our current programming."

When asked about resources in the interviews, participants spoke about webinars and newsletters:

> *I re-subscribed to that [environmental education newsletter] and I think from that I may have identified with one or maybe two webinars that we added to our online professional development calendar...we're always open to getting new resources from new people and so I may have actually borrowed something from that newsletter (PA-NP).*

Ideas

The participants mentioned that they used some ideas and practices learned from other participants in their environmental education programs. Based on Likert scale survey question, the mean score of using ideas in practices was 3.5 (Table 11). Some participants especially those who are non-traditional environmental educators, gained ideas to incorporate education into their programs. A participant explained how participating in PA SC impacted her view on environmental education and motivated her to incorporate environmental education into her practice:

> *We are just on a completely different vein… so meeting [another participant] and others that are involved specifically in that type of work I think definitely got my wheels turning as far as you know ideas about community engagement and education around that issue because right now we really haven't been doing a whole lot of education around it and don't even have our base of volunteers to help us…it got me thinking a lot … about how we really are …we've lost a little bit of the environmental education piece. This is made me think about ways I can be more intentional about this opportunity … now this experience has just really put my mind back in the environmental education vein so that I think that has helped (PA-K).*

Summary

The PA SC brought together a group of environmental educators and youth and community development professionals. Through different professional development activities

the participants shared information and exchanged ideas to inform their own practice. As a result of PA SC, the participants significantly increased the number of program goals; however, they reported little change in audiences, settings, and educational activities. In addition, the participants indicated that they already were using or intended to use new resources and ideas learned from the other participants in their practice.

Project-based Online Learning Community

The PLCP had 43 participants who stayed through the course and co-authored on an eBook. The response rates were 88% in the survey in the beginning of the program and 74% in the survey at the end of the program. Among those who responded to the surveys, only 30 (70%) responded to both surveys. Two participants who missed a few questions on practice elements were removed from the linear mixed-effects models.

After controlling for the participants' demographics including gender, race, age and work years, the PLC participants significantly increased the number of the activities in their practice (F (26) = 9.10, p = .006) (Table 12 and Table 13). However, the participants did not significantly change the number of goals (p = .259), audience race/ethnicity categories (p = .565), audience age groups (p = .170), settings (p = .432) and activities (p = .261). The change of age groups varied depending on participants' years of working experience, and the change of settings varied depending on participants' age and years of working experience. I included interaction between time of survey and each of the control variables (gender, race, age and work years) and dropped the ones that were not significant ($p < .1$).

For the number of audience age groups, the interaction between time of survey and work years was significant (p = .040). Specifically, among the participants with equal or more than 10 years working experience, the number of age groups after the program was significantly higher

than the number before the program (b = .5, SE = .18, t(25) = 2.61, p=.015). However, among the participants with less than 10 years working experience, the difference was not significant (p = .679).

Table 12. Change of practice elements based on check box questions in Project-based Online Learning Community

PLC	Before/ after program	Mean	SD
Number of goals	Before	6.57	2.52
	After	6.10	2.42
Number of race/ethnicity categories	Before	3.57	1.71
	After	3.71	1.54
Number of age groups	Before	3.57	1.91
	After	3.75	1.99
Number of settings	Before	4.14	2.19
	After	4.46	2.25
Number of activities	Before	7.11	2.12
	After	7.86	2.10

For the number of settings, the interaction between time of survey and age was marginally significant (p = .063). Specifically, among the participants who were 45 years old or above, the number of settings in their practice after the program was significantly higher than the number before the program (b = .94, SE = .39, t(24) = 2.41, p = .024). However, the difference was not significant (p = .982) among the participants who were under 45 years old. In addition, the interaction between time of survey and work years was marginally significant (p = .062). Specifically, among participant with less than 10 years working experience, the number of settings in their practice after the program was significantly higher than the number before the program (b = .91, SE = .33, t(24) = 2.79, p = .010). However, the difference was not significant (p = .923) among the participants with equal or more than 10 years working experience.

Table 13. The linear mixed-effects models results in Project-based Online Learning Community

	Number of Goals			Number of Race Types			Number of Age Groups					
	Den DF	F value	P value	Den DF	F value	P value	Den DF	F value	P value	Den DF	F value	P value
Gender	22	.40	.532	22	2.33	.141	22	.26	.614	22	.26	.614
Race	22	3.61	.071#	22	4.56	.044*	22	.08	.786	22	.08	.786
Age	22	.25	.620	22	1.29	.268	22	.10	.756	22	.10	.767
Work Year	22	.26	.616	22	1.87	.186	22	.22	.641	22	.22	.641
Time	26	1.33	.259	26	.34	.565	26	1.99	.169	25	2.52	.124
Time: Work Year										25	4.71	.040*

	Number of Settings						Number of Activities					
	Den DF	F value	P value	Den DF	F value	P value	Den DF	F value	P value	Den DF	F value	P value
Gender	22	1.06	.316	22	1.06	.316	22	1.29	.268	22	1.29	.268
Race	22	.67	.421	22	.67	.421	22	.90	.354	22	.90	.354
Age	22	.002	.961	22	.01	.961	22	.01	.909	22	.01	.909
Work Year	22	2.79	.109	22	2.79	.109	22	4.98	.036*	22	4.98	.036*
Time	26	1.86	.185	24	3.94	.059	26	9.10	.006**	22	29.93	.000***
Time: Gender										22	4.83	.039*
Time: Race										22	7.69	.011*
Time: Age				24	3.79	.063#				22	11.45	.003**
Time: Work Year				24	3.83	.062#				22	8.07	.010**

****p < .001; **p< .01; *p< .05; # p* < .1. Den DF stands for denominator degrees of freedom. Time stands for time of survey (before and after).

For the number of activities, the interactions between time of survey and each of the control variables were significant. First, the interaction between time of survey and gender was significant (p = .039). Specifically, the number of activities after the program was significantly higher than the number before the program among both female (b = 1.10, SE = .27, t(22) = 4.06, p = .001) and male participants (b = 2.2, SE = .48, t(22) = 4.55, p = .000). Male participants increased the number of activities more than did female participants. Second, the interaction between time of survey and race was significant (p = .011). The number of activities after the program was significantly higher than the number before the program among both nonwhite (b = 2.38, SE = .50, t(22) = 4.79, p = .000) and white participants (b = .93, SE = .27, t(22) =3.42, p = .003). Non-white participants increased the number of audience race/ethnicity categories more than did white participants. Third, the interaction between time of survey and age was significant (p = .003). The number of activities after the program was significantly higher than the number before the program among both the participants who were under 45 years old (b = .84, SE = .29, t(22) = 2.95, p = .007) and those who were 45 years old or above (b = 2.47, SE = .47, t(22) = 5.29, p = .000). The participants who were 45 years old or above showed a greater increase in number of activities than did those under 45 years old. Finally, the interaction between time of survey and work year was significant (p = .010). The number of activities after the program was significantly higher than the number before the program both among participants with less than 10 years working experience (b = 2.27, SE = .40, t(22) = 5.69, p = .000) and those with equal or more than 10 years working experience (b = 1.04, SE = .34, t(22) =3 .02, p = .006). The participants with less than 10 years working experience showed a greater increase in number of activities than did those with equal or more than 10 years working experience.

Goals

Participants mentioned a list of program goals, for example, pro-environmental behavior, ecosystem stewardship, positive youth development, community development, and foster sense of place or connection to nature. Participants also named several other goals that were not listed, for example, professional development for educators, environmental justice, academic achievement, and citizen participation in creating urban spaces. Based on Likert scale survey question, the mean score of changing goals was 3.0 (Table 14).

Table 14. Degree to which participants report changing practice elements based on Likert scale survey questions in Project-based Online Learning Community (N = 30)

	NA	Not at all	A little bit	Some	A lot	Totally	Mean	SD
Revised or added new goals	1	2	7	12	5	3	3.00	1.05
Involved different or more types of audiences	6	9	7	5	1	2	2.17	1.21
Expanded programs to new settings	4	12	5	4	2	3	2.19	1.39
Revised or developed new educational activities	2	4	5	9	6	4	3.04	1.24
Used new resources to inform the programs	2	3	8	8	3	6	3.04	1.30
Used ideas learned from other participants	2	3	8	6	6	5	3.07	1.28
Used ideas from the eBook	2	4	5	11	3	5	3.00	1.25

Some participants added more goals while others removed goals after the PLC. As a participant who added sense of place and connection to nature as new goals after the PLC explained:

> *Definitely it (PLC) made me realize that it's not enough to just take students outside. They have to be taken outside in different places. (PLC-D)*

A participant who removed mitigate environmental problem as a goal after the PLC explained:

> *So after the class I kind of ... my goals and planning, you know that they're taking baby*

steps, they need to get used to that before they're ready to measure air pollution or something like that. (PLC-MB)

Audiences

The PLC participants chose different types of race groups and age groups as their program audiences. Based on Likert scale survey question, the mean score of changing audiences was 2.17 (Table 14).

Some participants such as teachers may not have power to choose their program audiences. A participant who is a teacher mentioned that the ability to choose students depends on school enrollment. Another participant who works on pre-school garden projects did not add any age groups. She explained, "I don't get to pick my participants" (PLC-MB).

A participant who works in local government and added the age group (13-19) as a new audience explained:

Kids thirteen to nineteen we have to work with them early on and not wait for them to graduate from high school to make them aware that environmental work is a career choice…that's the kind of work is gaining some more and more support where I am in my department specifically. (PLC-BC)

Settings

The PLC participants identified different kinds of settings where they conduct their environmental education programs, for example, schools, public libraries, urban parks and other green areas, community gardens, urban farms, and green infrastructure. Based on Likert scale survey question, the mean score of changing settings was 2.19 (Table 14).

A college professor who changed her students' field work to an urban area explained:

I realize that I could actually make my plant ecology course instead of having the labs go on field trips … we would actually do urban plant ecology. And so I focused all my trips in the city. So they (students) will think about using the city in just a different way than I had actually never done before. The students really loved it. (PLC-BR)

A participant who added new settings such as natural areas explained:

> *We are changing our practice by getting off the campus like blowing into community and helping students and the public enjoy the environment where they live work and play, and then you know to grow and to grow in that experience but especially with children you know as they grow we want to grow with them*. (PLC-BC)

Some participants have a fixed setting such as nature centers and schools so they cannot expand to other places. A participant who works in a college explained: "…limited in the context of where I can take them because of the constraints of the institution where I work" (PLC-D).

Activities

The PLC participants named more kinds of educational activities after the program, for example, walking tours or neighborhood explorations, using online technology, hands-on science activities, environmental stewardship, visits to environmental facilities, recreation and environmental games or plays. Based on Likert scale survey question, the mean score of changing educational activities was 3.04 (Table 14).

A participant who added three new activities to her practice explained how the PLC gave her different perspectives and changed her way to teach and interact with kids.

> *It (PLC) gave me a different perspective and a realization that I need to connect to the kids on a different level or the program is not going to succeed… it gave me a different perspective that I met the other people who have the urban background. So I got a lot of help with that, how to teach them…Like with my kids in Brooklyn, that how I started the whole thing this year, because I realized that I could take them out to that site thousand times and they're going to stand there and avoid it unless I do something about it. So writing that chapter and finding that research totally changed the way I interact with them. (PLC-MB)*

Some participants who were reluctant to use social networking sites especially Facebook became more interactive on Facebook and even incorporated these tools into teaching. A participant who added new technology into her teaching explained:

> *So I am also make myself use much more social media to teach…I make them to use Tumblr, the journal, with focused questions of both focused topics. So as I become more comfortable with my own digital foot print, I will continue to use those media to engage these topics*. (PLC-D)

Resources

Participants indicated that they used some new resources to inform their environmental education programs. Based on Likert scale survey question, the mean score of using new resources was 3.04 (Table 14).

When asked about how the resources that they use for their programs changed as a result of participation in the PLC in the post-survey (Appendix 5), half of the respondents mentioned that their resources expanded in depth and breath. As a participant wrote, "I discovered numerous resources and collections shared by other participants on the FB page." These kinds of resources supported their programs. Another participant mentioned that, "PLC and resources helped to affirm and support changes that were in process before the PLC started."

Ideas

Participants indicated that they used some ideas and practices learned from other participants and from the eBook for their environmental education programs. Based on Likert scale survey question, the mean score of using ideas and practices learned from other participants was 3.7, and from the eBook was 3.0 (Table 14).

A participant explained how writing the eBook chapters helped her shape her ideas:

> *I had to do a ton of research. So seeing data to back up ideas, I think it helps a lot…Now I have that data, it really reinforces some of the ideas that everyone has. So I can put those into the practice…(PLC-MB)*

Participants showed their intent to use some ideas from the book into their practice in the future.

> *I think the ideas that are in the book will definitely help me…the one on bird habitat, that that may in the future be something that I work with you know local schools or you know community groups or whatever (PLC-B).*

Those new ideas could inspire the participants to enhance their environmental education

programs. A participant explained:

> *It really does inform my thinking about where we want to go with our programs and how we can increase both capacity and also to bring deeper content knowledge and information…I mean the case studies are amazing, they really are and I look through a lot and again just for inspiration to see whether people are doing and how they've reached out in what ways they've incorporated different messages. I mean it's been really helpful that has been a great resource. (PLC-T)*

Summary

The PLC participants interacted online to share and exchange ideas and resources and worked in small groups to co-author eBook chapters. As a result of the PLC, the participants significantly increased the number of educational activities and used new resources and ideas learned from other participants in their practice. In addition, the participants with equal or more than 10 years working experience significantly increased the number of age groups of audience in their practices. The participants with less than 10 years working experience and those 45 years or older significantly changed the number of settings in their practices. Finally, writing the eBook inspired and empowered the participants to enhance their practice.

Community Climate Change Fellowship

All 26 CCC participants responded to both surveys except one participant missed check-box questions in the survey in the beginning of the program; this participant was removed from the analysis. After controlling for the CCC participants' demographics including gender, race, age and work years, the participants significantly increased the number of the age groups ($F(24) = 6.40$, $p = .018$), settings ($F(24) = 4.38$, $p = .047$) and activities ($F(24) = 10.76$, $p = .003$) in their practice (Table 15 and Table 16). However, the participants did not significantly change their goals ($p = .286$) and audience race types ($p = .873$). I included interaction between time of survey and each of the control variables (gender, race, age and work years). However they were not significant ($p < .1$) and thus were dropped.

Table 15. Change of practice elements based on check box questions in Community Climate Change Fellowship

CCC	Before/After program	Mean	SD
Number of goals	Before	6.44	2.18
	After	5.92	2.02
Number of race/ethnicity categories	Before	3.00	1.61
	After	2.96	1.62
Number of age groups	Before	3.12	1.51
	After	3.56	1.45
Number of settings	Before	3.08	2.38
	After	3.44	2.22
Number of activities	Before	5.28	3.03
	After	6.12	2.99

Table 16. The linear mixed-effects models results in Community Climate Change Fellowship

	Number of Goals			**Number of race/ethnicity categories**			**Number of Age Groups**		
	Den DF	F value	P value	Den DF	F value	P value	Den DF	F value	P value
Gender	20	2.04	.168	20	.11	.745	20	1.67	.211
Race	20	2.41	.136	20	1.45	.242	20	.17	.683
Age	20	3.90	.062#	20	.002	.964	20	.18	.674
Work Year	20	.73	.401	20	2.24	.150	20	.42	.523
Time	24	1.19	.286	24	.03	.873	24	6.40	.018*
	Number of settings			**Number of activities**					
	Den DF	F value	P value	Den DF	F value	P value			
Gender	20	1.61	.219	20	1.21	.285			
Race	20	.77	.390	20	1.07	.314			
Age	20	2.69	.117	20	2.47	.131			
Work Year	20	.95	.341	20	.28	.605			
Time	24	4.38	.047*	24	10.76	.003**			

****p < .001; **p< .01; *p< .05; # p* < .1. Den DF stands for denominator degrees of freedom. Time stands for time of survey (before and after).

Goals

In the CCC, participants mentioned a list of program goals, for example, pro-environmental behavior, mitigating environmental problems, ecosystem stewardship, community

development and fostering sense of place. The participants also named a few other goals that were not listed, for example, foster cultural awareness and women's empowerment. Based on Likert scale survey question, the mean score of changing goals was 3.65 (Table 17).

Table 17. Degree to which participants report changing practice elements based on Likert scale survey questions in Community Climate Change Fellowship (N = 26).

	NA	Not at all	A little bit	Some	A lot	Totally	Mean	SD
Revised or added new goals	0	1	1	8	12	4	3.65	.94
Involved different or more types of audiences	1	1	7	9	5	3	3.08	1.08
Expanded the programs to new settings	4	4	4	8	3	3	2.86	1.28
Revised or developed new educational activities	1	2	4	8	8	3	3.24	1.13
Used new resources to inform the programs	1	0	2	4	14	5	3.88	.83
Used ideas learned from other participants	1	0	2	6	11	6	3.84	.90

Audiences

The CCC participants engaged more audiences mostly in two age groups: 13-19 years old and 20-39 years old. Based on Likert scale survey question, the mean score of changing audiences was 3.08 (Table 17).

In the survey, a participant talked about plans to reach out to more race groups in the future:

> *I am now developing a long-term plan for taking my work into non-white, Latino communities based on the Community EE approach presented in [guest speaker]'s trainings (CCC-S-MT).*

In the report, a participant explained how she recruited more audiences in her practice:

> *With wind in my sails and inspiration from other Fellowship projects, I was able to keep the fires burning on the project through the program development phase, recruiting over a dozen mentors and some prospective participants, while developing some instruments for running a focus group to tune program recruitment language and materials and begin development of curricula. I became savvier about climate change and climate justice*

education (CCC-MH).

Settings

The CCC participants indicated different settings where they conducted their programs, for example, schools, urban parks, community gardens, green infrastructure and nature centers. After the program, participants added other settings including local theaters, conference venues, community centers and churches. Based on Likert scale survey question, the mean score of changing settings from the Likert scale question was 2.86 (Table 17).

A participant who added local theaters as a setting explained:

> *(The action project) facilitates student coordination and hosting of a community-wide event at the local theater that provides a multi-dimensional series of presentations (art, student skits, local musicians) on local to global climate change causes, impacts, and solutions (CCC-EP)*

Activities

The CCC participants conducted a number of educational activities, for example, lessons indoors, walking tours or neighborhood explorations, creating and using media, using online technology, creating artwork, environmental stewardship, and visits to environmental facilities. Based on Likert scale survey question, the mean score of changing activities was 3.24 (Table 17). The participant who added local theater as a setting, also added educational activities such as creating artwork, creating and using media, and visits to environmental facilities. She explained:

> *(The action project) connects the students to local land and water protection entities across the island through service learning projects that engage students in on-the-ground solutions to climate change impacts (CCC-EP)*.

Another participant who added social media as an education activity said:

> *I'm more open to try new things and adding social media to my work has been both an eye opener and a real challenge, but much needed (CCC-S-VK)*.

Participants also mentioned that their climate change actions have expanded to

collaborate with more partners and increased impact at local and national level.

> *I am trying to collaborate with my local Museum of Art & History to create a project that allows teenagers to respond to climate change through art. I am also working with my schools to help the students identify a project to use their new knowledge to respond to CC. Some students are going to host an informational fair teaching their families and friends how they can take action by reducing their carbon footprint (CCC-SJ).*

> *News of my consulting and leadership training services have spread by word of mouth and I have been invited to do three local public speaking events and one long-distance webinar on climate change in the next three months, as well as to deliver a Climate Courage leadership training workshop for 20-30 local ministers from different denominations who would like to start a Courageous Conversation on climate change in their congregations, with the long-term goal of establishing a Climate Change Ministry. The biggest development of all is that I have been invited out-of-state to Moscow, Idaho to design and present a 2-day Climate Change Community Forum featuring my work ...I have also been invited to deliver a conference paper on my work…(CCC-MT)*

Resources

Although we did not ask participants to check off resources before and after the professional development activities, in the open-ended survey participants mentioned that they have used materials learned from the CCC in their project. Based on Likert scale survey question, the mean score of using new resources was 3.88 (Table 17).

A participant talked about how she learned about resources that could be incorporated into her practice:

> *I learned about many resources that explain climate change in simple, easy to understand language that I used (or revised to use) with our participants. Many were suggestions by CCC colleagues, or I discovered them by following up on suggestions. It was helpful to hear feedback from people who had used the resources, to hear what was useful or not, so I could include this in my preparations (CCC-S-NL).*

Specifically, responding to the open-ended survey question, participants indicated that the materials shared by other participants and guest speakers at the workshop were very helpful for their projects.

> *I have added several new resources including people to bounce ideas off from (CCC participants and leaders), as well as community development materials (via guest*

speaker) to enhance my programming (CCC-S-JH).

Ideas

Participants indicated that they have incorporated ideas and practice learned from other participants into their projects. The mean scores of using new ideas and practices was 3.69 (Table 17). A participant mentioned how she used learned lessons into her practice:

> *I now pull from the lessons learned shared by the CCC fellows, as well as incorporate their ideas into my curriculum (CCC-S-EP).*

Summary

The CCC participants designed and implemented their action projects but did not significantly change the number of program goals nor ethnic groups in their practice. However the participants significantly engaged more age groups, expanded to more settings, and conducted more educational activities. Several participants expanded their activities to include professional training for other educators. In addition, the participants indicated that they incorporated new resources and ideas into their practice.

Discussion

Across all three professional development programs, educators incorporated new resources and ideas into their practice. Previous studies showed that environmental educators intended to adapt ideas learned from online professional development activities into their practice (Y. Li et al., 2014) and that non-formal educators adapted resources learned from interacting with school teachers into their teaching practice (Bainer et al., 2000). In this study, all three professional development programs were designed for participants to share and exchange ideas and information. The ideas and resources appeared to be relatively easier to adapt than other practice elements such as goals, audiences, settings and educational activities. These new resources and ideas could inform participants' environmental education practice and may lead to

practice change given enough time.

However, changes in the other practice elements varied among programs, which might have been caused by due to different purposes and interventions of the programs. The practice element goals only shifted in the PA SC, which was specifically designed to bring together environmental educators and youth and community development professionals who might have different goals. Through professional development activities, participants who focused on environmental education tried to expand the program to engage in community oriented work. Also those who worked on youth and community development were urged to consider including an environmental education component to their programs. In contrast, the PLC was specifically designed for environmental educators who were interested in conducting environmental education programs in urban areas and the CCC was specifically designed for environmental educators who developed community climate change action projects to address climate change related issues. Both the PLC and CCC had specific topics for participants to work on, thus participants may have been less likely to shift their program goals after the professional development activities. However, results from Likert scale questions showed the PLC and CCC participants significantly changed their goals. A possible explanation is that the choices for goals in check box questions overlap with each other. Participants may have several goals that fall under one choice. Thus participants who reported few changes in check box questions considered those changes significant in Likert scale questions. It also could be that participants report their perceptions or even expectations of degree of change subjectively relative to actual change.

The practice elements age groups of the audiences and settings only changed in the CCC and for the PLC participants with 10 or more years working experience. The CCC participants developed new community climate change action projects as part of the professional

development program. Also two-thirds of participants worked with non-formal environmental education programs. Participants might have more flexibility to engage more age groups and expand to new settings than participants in the other two groups. In the PA SC and PLC, participants incorporated learned ideas into existing practices rather than developing new practices. Thus, participants might lack of control over elements of the practice such as audiences and settings. Especially school teachers may have less flexibility when it comes to changing practice relative to non-formal educators due to the constraints of schools for environmental education practices such as curriculum standards and school-level organization (Fazio & Karrow, 2013).

The practice element educational activities changed in both the PLC and CCC. In the PLC, which had only online interactions and produced an eBook, the participants conducted more types of activities. Given the group focused on environmental education practice in an urban context, the participants were more likely to add educational activities learned from others than to add other practice elements such as goals, audiences and settings. Further, participants co-authored the eBook from which they may have learned about diverse urban environmental education programs and incorporated learned activities into their practice. In the CCC, participants were required to develop new community climate change practices as part of the professional development program. They received more targeted training sessions than did the other two groups, which allowed them to incorporate learned educational activities into their practices right away. In contrast, in the PA SC without any collaboration on projects or development of new projects, participants had not adapted learned educational activities into their practices.

This study investigated change in practice elements, which provided a new approach to

measure the impact of professional development programs in education. Although some studies examined teaching practice as a result of professional development programs, they simply asked teachers to report if they had changed their teaching practice rather than inquire about specific practice elements (Sondergeld et al., 2014). By examining specific elements of practice, researchers in other fields are able to understand the practice in depth. Studies, which applied practice theory to professional learning in industry, used practice attributes including challenges, opportunities, and interactions (Reich, Rooney, Gardner, et al., 2015), and process including participation in practice, construction of knowledge, and becoming professionals, to conceptualize learning processes of engineers (Rooney et al., 2012). To measure specific change in practice, this study suggested that the elements could be identified more specifically to reflect the practice in a certain context. To apply practice theory into environmental educational contexts, special attention should be paid to develop practice elements based on key characteristics of environmental education practice.

The study also suggests that practice theory may be a useful means for understanding environmental education practice. Adding to previous research using conceptual elements in consumers studies (Shove & Pantzar, 2005), professional learning in industry (Rooney et al., 2012) and environmental stewardship (Krasny et al., 2015), this study identified six applied elements -- goals, audiences, settings, educational activities, resources and ideas -- to construct an environmental education practice. These elements were chosen based on previous research that included them as characteristics of environmental education practice (Ashmann & Franzen, 2015; Eames et al., 2008; Y. Li et al., 2014; Stern et al., 2013). By bridging practice theory (Reckwitz, 2002) and environmental education characteristics, I was able to examine a comprehensive list of elements that define an environmental education practice.

Limitations

This study relied on participants' self-report to check box questions and Likert-scale questions rather than actual observation to examine their practice change. The check box questions provided evidence of specific changes in each practice element. But the choices for each practice element might either overlap with each other or not cover all possibilities. The Likert scale questions measured degree to which each practice element changed. Without indicating specific change, these changes could be participants' perceptions or expectations instead of real changes in practice. Future research should conduct observations or in-depth interviews to examine what participants changed in their practice. In addition, the study did not conduct control groups to compare the change. Although I asked participants to report their changes as a result of our professional development programs, some other factors may impact the changes. Finally, this study did not conduct a follow-up survey to examine the long-term effects of professional development programs. Some practice elements may take time to change. These shortcomings could be addressed by a longitudinal study that conducts observation with both treatment and control groups.

Conclusion

This study applied practice theory to examine outcomes of professional development programs in environmental education. It added a new lens to evaluate the impact of professional development programs and expanded practice theory to environmental education practice. I used six elements to describe an environmental education practice: goals, audiences, settings, educational activities, resources and ideas. By identifying different elements, researchers can better understand environmental education practice. Also educators should be able to analyze their practices in detail and make appropriate adjustment to improve practice. The change of the

practice elements could also serve as indicators of innovation. Future research should consider linking practice theory to social innovation (Pantzar & Shove, 2010; Shove & Pantzar, 2005) in an environmental education context.

CHAPTER 4

RELATIONSHIP BETWEEN NETWORKS AND PRACTICE CHANGE IN ENVIRONMENTAL EDUCATION

Abstract: Environmental educators use social networks to exchange ideas and practice. This study examines the relationship between network characteristics -- in-degree, out-degree, closeness, and betweenness centrality and tie strength -- and practice change in three professional development programs. I conducted network surveys and social network analysis to measure network characteristics, surveys to measure practice change, and correlation analysis to investigate their relationships. Practice change was indicated by the sum of change of practice elements including goals, audiences, settings, activities, resources and ideas. The results showed that participants' in-degree, out-degree, closeness, and betweenness centrality and tie strength were positively associated with practice change in the PA SC that used face-to-face professional development activities, and that participants who occupied central and brokerage positions were more likely to change their practice. Only in-degree centrality was positively associated with practice in change in the PLC, which had only online activities, indicating that educators who occupied central positions were more likely to change their practice in this program. However, in the CCC with both face-to-face and online activities and the highest network density, no significant associations between network characteristics and practice change were measured. The results help us understand the role of developing professional networks in participants' practice change through different professional development programs.

Key words: Professional networks, practice change, and professional development

Introduction

Interactions and collaborations with others is a critical aspect of teacher development (B. Bell & Gilbert, 1996). Educator networks enable teachers to develop and maintain social relations to support and sustain learning (Chalmers & Keown, 2006; Goodyear et al., 2004; Lieberman, 2000; Stoll et al., 2006), provide opportunities for feedback that facilitates reflection on one's teaching practice (Akerson et al., 2009), and positively impact teaching practice (Vescio, Ross, & Adams, 2008). Further, social networks can facilitate information transfer, and therefore can play a key role in the generation and diffusion of social innovations (Abrahamson & Rosenkopf, 1997; Moore & Westley, 2011).

Social network analysis provides a means to understand how individuals connect to each other (Scott, 2000) and has been used to examine the interactions among learners in online (Cela et al., 2015) and face-to-face educational settings (de Lima, 2010; McFarland et al., 2011). For example, studies using social network analysis have examined the relationship between network structural properties, including degree, closeness, and betweenness centrality (Freeman, 1979), and students' academic achievement (Cho et al., 2007; Russo & Koesten, 2005). Scholars also have studied the influence of social networks on individual creativity (Perry-Smith, 2006), the influence of relational quality on knowledge sharing between individuals (Bouty, 2000), and the influence of social network structure on the diffusion and adoption of innovations (Bothner, 2003). Importantly, an individual's position in the network impacts outcomes such as knowledge construction (Phelps, Heidl, & Wadhwa, 2012), sense of belonging (Haythornthwaite, 2001), sense of community (Dawson, 2008), academic persistence (Eckles & Stradley, 2012), social integration (Thomas, 2000), job opportunities (Yakubovich, 2005), job performance (Sparrowe, Liden, Wayne, & Kraimer, 2001), and leadership, power and innovation (Wasserman & Faust,

1994). A growing body of research also has examined the impact of networks on teacher outcomes in professional development programs (Moolenaar, Daly, Cornelissen, et al., 2014; Penuel et al., 2012). However, little is known about the relationship between educators' network structural properties and their teaching practice or how network structures impacts innovation in professional development programs.

The aim of this study is to explore the relationship between professional networks and educators' practice as a result of professional development activities. Drawing on the social network analysis results from Chapter 2 and practice elements change results from Chapter 3, I conducted correlation analysis to examine the relationship between network structural characteristics and educators' practice change. My specific research question was: What is the relationship between network centrality (in-degree, out-degree, closeness and bewteenness) and tie strength, and practice change? The results will help us understand the impact of networking through professional development activities on practice change in environmental education.

Literature review

Four bodies of social network analysis research reveal findings important to education and professional development: the influence of networks on learning performance, networks and outcomes for teachers, networks and the generation of innovations, and networks and innovation diffusion. I discuss each of these below.

Networks and learning performance

Studies of the relationship between network structure and students' learning performance have found a significant positive association between in-degree, out-degree and closeness centrality, and students' academic performance (Baldwin, Bedell, & Johnson, 1997; Hommes et al., 2012; Thomas, 2000; Yang & Tang, 2003). For example, R. A. Smith and Peterson (2007)

found that in-degree centrality in a college class related advice network had a significant positive relationship with students' final grades, indicating that a student performed better if more classmates asked the student for class related advice. Russo and Koesten (2005) found network in-degree centrality and out-degree centrality had a significant positive relationship with students' final grades in an online graduate class and Joksimović et al. (2016) found a positive relationship between in-degree centrality and the likelihood of completing a MOOC. One explanation for these results is that learners with high in-degree centrality play a central role in the network and have access to more resources (Brass, 1984). Further studies on the relationship between closeness centrality and students' academic performance suggested that students who had shorter distance to other students had higher academic performance (Cho et al., 2007; Gašević, Zouaq, & Janzen, 2013) and were more likely to obtain course certificate in a MOOC (Joksimović et al., 2016). These students had "ease of access to others" (Burkhardt & Brass, 1990, p. 113), which indicates more direct and quicker access to resources.

The relationship of network structural properties to students' academic performance may vary depending on context. Jiang et al. (2014) found a significant positive association between two centrality measures (degree and betweeness) and final grades in a MOOC on Algebra, but not in a MOOC on financial planning. The authors suggested that the financial planning MOOC was assisting people in life skills so the learners might not be concerned about obtaining a certificate. In contrast, in the academic Algebra MOOC, the learners cared more about the certificate so that how often a learner interacted with other learners in a discussion forum impacted the learner's final grades. Further, Cho et al. (2007) found no significant relationship between betweenness centrality and students' grades in an online engineering course. The authors attributed this result to the limited importance of betweenness centrality, a measure of

control over strategic information and resources, in educational settings. In educational settings, more and quicker access to other participants, as measured by degree centrality and closeness respectively, would be more important for learners.

Networks and teacher outcomes

Several studies explored the relationship between aspects of network structure and teacher outcomes. For example, Penuel et al. (2012) asked teachers to list colleagues who provided them with help related to teaching writing to students, which could be considered as measuring out-degree centrality. They found that teachers who interacted with colleagues who had prior professional development training changed their own practice. However, these researchers did not measure other network structural properties. Moolenaar, Daly, Cornelissen, et al. (2014) examined the relationship between educators' in-degree and out-degree centrality, network intentionality (the extent to which an educator is intentional in interacting with others), and perceptions of innovative climate in school (school open to innovation, and educators willing to share and adapt new ideas into practice). The results showed that both out-degree centrality and network intentionality had significant positive relationships with educators' perception of innovative climate. However the study did not examine actual innovation or change in teachers' practice.

Networks and Innovation Generation

Innovations in professional and voluntary practice often emerge from cross-disciplinary and cross-sector activities (Biggs et al., 2010; Davidson-Hunt, 2006; Tsai, 2001). This suggests that creating professional development opportunities that bring together professionals with different kinds of knowledge to exchange ideas, experience, and other resources will foster innovations in education (Penuel et al., 2012; Roling & Wagemakers, 2000; K. G. Smith, Collins,

& Clark, 2005). Professional development activities may serve a role similar to bridging individuals or organizations, which link diverse actors or groups to facilitate communication (Crona & Bodin, 2006) and collaboration (Crona & Parker, 2012).

Empirical studies have linked network structure to the generation of innovations. Several studies found that the positions of firms in inter-organizational networks impact their innovation output. For example, at the group level, K. G. Smith et al. (2005) found that aggregated centrality measured by number of direct contacts among workers in a firm had a positive impact on the firm's innovation measured by new products, which indicated that the denser a network was, the more innovation it produced. Studies also found that a firm's degree centrality measured by number of cooperative relationships with other firms had a positive impact on its innovation output (Ahuja, 2000; Shan, Walker, & Kogut, 1994; Tsai, 2001).

The strength of network ties influences knowledge creation, which is closely tied to innovation. K. G. Smith et al. (2005) found that strength of ties measured by duration of relationship, frequency of interaction, and emotional intensity of key contacts, was positively related to innovation measured by number of new products. McFadyen and Cannella (2004) suggested that the strength of ties had an initial positive effect and then with increasing tie strength changed to a negative effect (in an inverted U-shape) on knowledge creation measured by impact factor of publications in biomedical research. Weak ties may be more likely to give rise to innovations than strong ties (Burt, 2004; Granovetter, 1973). Moore and Westley (2011) suggested that the actual generation of the innovation may require many weak and diverse ties, but the adoption of the innovation requires strong bonds and trust so the network structure must evolve throughout the process.

Innovation Diffusion

Social network density, position, and structure influence innovation diffusion and adoption. At the group level, studies have shown that density promotes innovation adoption by increasing information availability (Abrahamson & Rosenkopf, 1997), increasing the rate and extent of information diffusion in a network (Fleming, Mingo, & Chen, 2007; Reagans & McEvily, 2003; Singh, 2005), and encouraging cooperation among individuals in the network (Obstfeld, 2005). At the individual level, an individual's network centrality had a positive influence on innovation adoption (Burt, 2004). Studies also suggested that more ties to prior innovation adopters (Strang & Tuma, 1993) and larger networks in an organization (Morrison, 2002) increased the likelihood of innovation adoption. Innovators with more structural holes could access diverse information (Burt, 2009), and provide efficient sources of useful information, which increases the possibility of attracting others to adopt their ideas (Nerkar & Paruchuri, 2005). However there is a trade-off between network structure diversity and information diffusion (Aral & Van Alstyne, 2011; Lazer & Friedman, 2007).

In addition to network structure, strength of network ties impacts innovation diffusion and adoption. Weak ties provide access to diverse groups of individuals and external resources (Granovetter, 1973; Newman & Dale, 2007), and are used for information exchange and to foster trust among previously unconnected groups (Bodin & Crona, 2009; Crona & Parker, 2012). However, other studies argued that strong ties, which could help establish trust and reciprocity norms and promote intense information sharing (McFadyen, Semadeni, & Cannella, 2009), are more effective than weak ties in enhancing information transfer and learning (Bouty, 2000; Levin & Cross, 2004; Uzzi & Lancaster, 2003). In addition, social reinforcement from multiple individuals to which an individual connects, may increase the likelihood of the individual's

adoption of innovation (Centola, 2010).

The degree of homophily also affects the diffusion of innovation. The principle of social homophily argues that people tend to choose others who are similar to them as friends (McPherson et al., 2001; Newman & Dale, 2007). Similarly, interpersonal diffusion networks are mostly homophilous, which means that individuals tend to be linked to others who are similar and close to them in geographic distance. The geographic distance between contacts in a network influences their information diffusion (Phelps et al., 2012). Geographic proximity may enable fast information transfer, but the shared information will be more homogenous within a geographic region than across regions (G. G. Bell & Zaheer, 2007) so that the information shared is less novel than information shared between geographically distant persons. Similarly, individuals with similar expertise can communicate more efficiently (Black, Carlile, & Repenning, 2004; Reagans & McEvily, 2003), but the shared information would be more redundant between them than between individuals with diverse expertise. Thus the way to diffuse innovation across groups is to have between-group brokers (Burt, 2004) to build and broker relationships and to broker knowledge and resources (Moore & Westley, 2011).

Methods

In this study, I examined the relationship between educators' networks and their practice change. Informed by practice theory (Reckwitz, 2002) and a professional framework that emphasizes social development (B. Bell & Gilbert, 1996), I used social network analysis to identify network structural properties and tie strength, and use surveys and interviews to evaluate the impact of these changes on practice.

Participants

Participants are described in Chapter 1: Introduction.

Measurements

To answer the question about the relationship between network properties and practice change, I conducted bi-variate Pearson correlation tests. This text is used in Cho et al. (2007) because it is robust in the presence of inter-correlation between different centrality measures (Table 18). The variables included six network measures (in-degree, out-degree, closeness and betweenness centrality, and in-degree and out-degree tie strength) and number of change of practice elements (see measurements in Chapter 2 and Chapter 3).

Table 18. Descriptive statistics of network measures among respondents.

Network metrics	PA (N = 15)		PLC (N = 28)	CCC (N = 25)
	Pre	**Post**	**Post**	**Post**
In-degree				
Mean	5.60	11.93	1.82	12.60
Median	5.00	12.00	2.00	12.00
Range	0-13	7-16	0-3	10-18
Out-degree				
Mean	5.87	14.33	2.14	12.48
Median	6	15	1.5	8.00
Range	1-15	1-26	0-10	0-25
Closeness				
Mean	.50	.71	.11	.70
Median	.52	.70	.14	.60
Rang	.33-.71	.43-1.00	0-.27	0-1
Betweenness				
Mean	35.40	16.18	18.25	16.23
Median	20.15	8.00	7.25	6.89
Rang	0-132.9	0-55.00	0-88.50	0-55.66
In-degree tie strength				
Mean	.83	1.97	2.02	1.49
Median	.92	1.93	2.00	1.50
Range	0-1.73	1.42-2.50	1.5-3	1.10-2.07
Out-degree tie strength				
Mean	.98	1.89	1.95	1.59
Median	.77	1.88	2.00	1.49
Range	.2-2.67	1.17-3.00	1-2.5	1-3

In the social network surveys, I added the question about frequency of contact (5: daily, 4: several times a week, 3: several times a month, 2: several times a year, 1: once since the program). The more frequently one participant contacts another, the stronger the tie between them. A participant's in-degree tie strength was calculated by the mean score of contact frequency the participant received from others. A participant's out-degree tie strength was calculated by the mean score of contact frequency the participant contacted others. For example, if participant A contacted participant B daily, and contacted participant C once since the program, the out-degree tie strength after the program for participant A was (5+1)/2 = 3.

Validity

I used triangulation to enhance the validity of the research (Carmines & Zeller, 1979). Convergent validity was addressed by comparing the surveys and interviews results.

Results

For each professional development program, I report correlations between network measures (in-degree, out-degree, closeness and betweennes, and in-degree and out-degree tie strength) and practice change, and survey and interview results. Whereas, all three structural measures demonstrated a significant positive relationship with practice change in the PA SC, only in-degree centrality had a significant positive relationship with practice change in the PLC, and there was no significant relationship between network measures and practice change in the CCC. Survey and interview results suggested that educators perceived an impact of sharing resources and ideas with other educators on their practice in all three practices.

Pennsylvania State Consortium

In-degree centrality before and after the program was significantly associated with the PA SC participants' practice change indicated by number of practice elements change (r = .715, p = .003; r = .662, p = .007, respectively). The PA SC participants who received more nominations by other participants as information providers before and after the program were more likely to change practice.

Whereas out-degree centrality before the program also had a significant positive relationship with the PA SC participants' practice change (r = .707, p = .003), the relationship between out-degree centrality after the program and practice change was not significant (r = .313, p = .256). The results indicate that those who seek advice before the program were more likely to change practice after the program.

Similarly, closeness centrality before the program had a significantly positive relationship with the PA SC participants' practice change (r = .663, p = .007), whereas there was no relationship between closeness centrality after the program and practice change (r = .276, p = .320). The results indicate that those who had shortest distance to other participants before the program were more likely to change practice after the program.

In addition, betweenness before and after the program was significantly associated with the PA SC participants' practice change (r = .705, p = .003; r = .708, p = .004, respectively). These results indicate that those who occupied brokerage positions in the network were more likely to change their practice.

Further, in-degree tie strength before and after the program were significantly associated with the PA SC participants' practice change (r = .555, p = .032; r = .543, p = .036, respectively), which indicated that participants receiving with stronger connections from others were more

likely to change their practice. However out-degree tie strength before and after the program showed no significant relationship with the PA SC participants' practice change (r = .216, p = .440; r = .343, p = .210, respectively).

Table 19. Correlations between network properties and practice change before and after professional development program in Pennsylvania State Consortium (N=15).

Pre-program	In-degree	Out-degree	Closeness	Betweenness	In-degree tie strength	Out-degree tie strength
Practice change	.715** p = .003	.707** p = .003	.663** p = .007	.708** p = .003	.555* p = .032	.216 p = .440
Post-program	In-degree	Out-degree	Closeness	Betweenness	In-degree tie strength	Out-degree tie strength
Practice change	.662** p = .007	.313 p = .256	.276 p = .320	.700** p = .004	*.543** p = .036	.343 p = .210

***p < .001; ** p < .01; *p < .05

In Likert scale survey questions to determine what factors educators perceived influenced their change in practice (Table 20), interacting with other participants had the highest mean score, with 13 of 17 respondents (76%) saying they strongly agreed or agreed. In addition, 12 out of 17 respondents (71%) indicated they strongly agreed or agreed that interacting with co-leaders and participating in face-to-face workshops influenced their practice change and 11 out of 17 respondents (65%) said that they strongly agree or agreed that participating in webinars influenced their practice change. When asked about the impact of participating in Facebook discussion, 5 out of 17 respondents chose not applicable and 4 participants chose disagree indicating that fewer participants were active on Facebook.

Table 20. Degree to which participants report factors that influenced their practice change based on Likert scale survey questions in Pennsylvania State Consortium (N = 17).

Degree	NA	1	2	3	4	5	Mean	SD
Interacting with other participants	3	0	0	1	10	3	4.14	.54
Interacting with the PA SC co-leaders	2	0	0	3	8	4	4.07	.70
Participating in workshops	2	0	1	2	8	4	4.00	.85
Participating in Webinars	2	0	1	3	9	2	3.80	.78
Participating in Facebook discussion	5	0	4	3	2	3	3.33	1.23

Header: 1: Strongly disagree; 2: Disagree; 3: Neither disagree nor agree; 4: Agree; 5: Strongly agree. The numbers in the table represent the number of respondents.

In interviews, the PA SC participants mentioned how connecting to other participants influenced their environmental education practice. A participant explained how ideas from other participants helped her think differently:

> *We are just on a completely different vein… so meeting [another participant] and others that are involved specifically in that type of work I think definitely got my wheels turning as far as you know ideas about community engagement and education around that issue because right now we really haven't been doing a whole lot of education around it and don't even have our base of volunteers to help us…it got me thinking a lot … about how we really are …we've lost a little bit of the environmental education piece. This is made me think about ways I can be more intentional about this opportunity … now this experience has just really put my mind back in the environmental education vein so that I think that has helped (PA-KH).*

Another participant mentioned that he applied what he learned from other participants in his practice:

> *I've used a lot of activities and sort of knowledge that was came through the community of learners in our meetings and webinars and face-to-face meetings to bring those practices into play within the community groups that we work with. That's built some community development that's given us more volunteers that increased our capacity to do work. It allowed my staff to become involved with other efforts that they normally would not have been involved. So to me that's capacity building…(PA-RH)*

In addition to direct impact on practice, participants mentioned that they received support from each other, which might influence their practice indirectly such as applying for grants and

networks.

> *Most of the new networks provide us with additional support for when we do community projects they could be providing financial in kind support if their volunteers were working with us on a project. They could provide us with letters of support for grants submission that we would put in, they are very localized. They could provide us with resources and materials from local companies and businesses and corporations that might be able to offset some of our costs that we would have to apply for in a grant. And these groups that are in the new networks are people that know the landscape much more better...than we do if we're not always in that particular county or in those rivers and streams. ...that they'll have established relationships with to build stronger coalitions for community based projects. (PA-RH)*

However, a participant with years of experience who gained high in-degree centrality and out-degree centrality after the program did not indicate change in her practice. She mentioned in the post-survey: "Since my background is in EE [environmental education], I did not gain a lot of content knowledge or skill-sets. And since I do not work directly with youth or youth programs, I did not have an opportunity to use new information, curricula…" She provided information and resources for other participants.

> *So a lot of the information was not new to me. So I think that I probably did not benefit from this project as much as other people did... I think I came in with a lot of background knowledge in these areas and I think it was much more useful to people that were maybe mid-career you know so people that were really just now learning about environmental education or learning about after school or learning about museum partnership. So whereas I think I provided a lot to the group I don't think I got enough out of it anyway. (PA-NP)*

Project-based Online Learning Community

In-degree centrality after the program was significantly associated with educators' practice change (r = .396, p = .037, Table 5), which indicated that the PLC participants who received more nominations by other participants as information providers after the program were more likely to change practice. The other network variables did not have significant association with practice change.

Table 21. Correlation between network properties and practice change in Project-based Online Learning Community (N = 28).

Post-program	In-degree	Out-degree	Closeness	Betweenness	In-degree tie strength	Out-degree tie strength
Practice change	.396* *p = .037*	– .041 *p = .837*	.068 *p = .731*	.147 *p = .457*	.214 *p = .294*	– .394 .127

*$p < .05$

In Likert scale survey questions to determine what factors the PLC participants perceived influenced their change in practice (Table 22), 21 out of 30 respondents (70%) strongly agreed or agreed that participating in writing the eBook had impacted their practice change. Also 18 of 30 respondents (60%) strongly agreed or agreed that interacting with other participants and facilitators had impacted their practice change. In addition, 12 (40%) respondents strongly agreed or agreed that Facebook discussion had impact their practice change, and 11 (37%) strongly agreed or agreed that participating in webinars had impacted their practice change. Fewer respondents (27%) agreed that interacting with outside speakers had impacted their practice change.

Table 22. Degree to which participants report factors that influenced their practice change based on Likert scale survey questions in Project-based Online Learning Community (N = 30).

Degree	NA	1	2	3	4	5	Mean	SD
Participating in writing eBook	1	2	1	5	9	12	3.97	1.18
Interacting with other participants	1	2	1	8	14	4	3.59	1.02
Interacting with the facilitators	1	1	3	7	14	4	3.59	.98
Participating in Facebook discussion	4	3	1	10	10	2	3.27	1.08
Participating in Webinars	3	2	2	12	10	1	3.22	.93
Interacting with outside speakers	5	2	2	13	7	1	3.12	.93

Header: 1: Strongly disagree; 2: Disagree; 3: Neither disagree nor agree; 4: Agree; 5: Strongly agree. The numbers in the table represent the number of respondents.

In the interview, a participant who increased educational activities explained that connecting to other participants gave her different perspectives to teach her students:

> *It gave me a different perspective that I met the other people who have the urban background. So I got a lot of help with that. Because to me, I grew up very differently, so I'm thirty years older than these kids, I am a different race, so there are not a lot to connect over. So it gave me a different perspective. How to teach them. (PLC-MB)*

Through networking with other participants, a participant made a local connection and expanded her practice to a new setting:

> *So one big connection that I made through the program through the course and our networking on Facebook and phone calls was that I met somebody that works with [name] and she connected me with [name] at Patterson Park right in the middle of Baltimore City … they had been interested in maybe trying to bring in some college students interactions. So I actually had my plant ecology class in the fall, go out to Patterson Park and we did some surveying of some gardens they had set up and help them to figure out what was still there. So I get my students to learn some skills and identification and then also provided this service to Patterson Park Audubon… That was a really nice connection we've stayed connected in the consistently recently to see if I want to come back so that that was a very tangible local connection that I made. (PLC-BR)*

Community Climate Change Fellowship

The correlation analyses showed no significant association between post-program network characteristics and practice change in the CCC (Table 23).

Table 23. Correlation between network properties and practice change in Community Climate Change Fellowship (N = 25).

Post-program	In-degree	Out-degree	Closeness	Betweenness	In-degree tie strength	Out-degree tie strength
Practice change	.025 $p = .906$	– .098 $p = .643$	– .067 $p = .751$	– .267 $p = .197$	.166 $p = .427$	– .223 $p = .295$

In Likert scale survey questions to determine what factors the CCC participants perceived influenced their change in practice (Table 24), 24 out of 26 participants (92%) strongly agreed or agreed that interacting with other participants and facilitators, and participating in the face-to-face workshop had impacted their practice change. Also 20 participants (77%) strongly agreed or agreed that participating in the NAAEE conference, and interacting with speakers at the

workshop and the conferences had impacted their practice change. In addition, participants indicated that Facebook discussions, webinars and conference calls had impacted their practice change.

Table 24. Degree to which participants report factors that influenced their practice change based on Likert scale survey questions in Community Climate Change Fellowship (N = 26).

Degree	NA	1	2	3	4	5	Mean	SD
Participating in the face-to-face workshop	1	0	0	1	12	12	4.44	.58
Interacting with the program facilitators	0	0	0	2	12	12	4.39	.64
Interacting with other participants	0	0	0	2	13	11	4.35	.63
Participating in the NAAEE conference	3	0	0	2	14	7	4.22	.60
Interacting with speakers at the workshop	1	0	0	4	15	6	4.08	.64
Interacting with speakers at the NAAEE conference	1	0	0	4	17	4	4.00	.58
Participating in online Facebook group discussion	2	0	2	8	12	2	3.58	.78
Participating in webinars	4	0	0	11	11	1	3.57	.59
Participating in monthly conference calls	1	0	1	11	12	1	3.52	.65

Header: 1: Strongly disagree; 2: Disagree; 3: Neither disagree nor agree; 4: Agree; 5: Strongly agree. The numbers in the table represent the number of respondents.

In the reports, when asked how networking helped the CCC participants develop their climate change action plans, the participants mentioned how they gained resources and ideas from networking with other participants. A participant explained how networking with other participants helped her develop ideas for her project and receive advice from others:

> *Prior to my participation in the Community Climate Change Fellowship, I had a difficult time framing the format of a summer program that could engage high school students in climate activism. I had a difficult time organizing my ideas and making decisions for this project. After attending the conference in West Virginia and speaking with other participants I was able to organize my thoughts and design a feasible project. It was tremendously helpful to learn about their own experiences and receiving their advice. (CCC-JR)*

Participants applied what they have learned from other participants into their practice. A participant who had higher in-degree and out-degree centrality indicated in the survey that she engaged more age groups, expanded to a new setting and used new educational activities through the program. She also explained in her final report:

> *I have worked with the other fellows to learn more about ways to broaden our youth program focus to include additional fields of study (such as art and music), additional entities (such as churches, etc.), new experiences, and a wider range of people. Doing so has inspired us to aid the students to outreach to their own communities in a much more formalized manner. (CCC-EP)*

Through networking, participants exchanged resources with each other. A participant explained in the report how he applied resources in his practice and shared with his colleagues:

> *Having the fellows as a network for sharing successes and resources has also been wonderful and regularly find myself utilizing resources shared on our Facebook page in my own work and sharing the resources with my 120 education volunteers and 40 staff (CCC-AR)*

These networks sustain over time and continue providing resources for participants. A participant mentioned in her final report (6 months after the initial face-to-face workshop) how she stayed in touch with other participants:

> *The thing that was most beneficial to me at the training was being given the opportunity to talk with other fellows (during and after our presentations) … Since then, there are three or four fellows with whom I have remained in consistent contact either to provide them with resources, share CC101 (climate change) PowerPoints and information, or to get their feedback on what I am doing. (CCC-JH)*

Participants also collaborated on projects. A participant explained how her school was considering incorporating another participant's project into their curriculum:

> *We have had preliminary discussions with one of my fellows, JD. His Climate Stories Project is a perfect fit for the curriculum and culture of (high school). The faculty at (high school) is very interested in how we can integrate JD's project into their curriculum, and tie it into the overall work of my climate change project. (CCC-ME)*

In addition to interacting with each other, participants mentioned how they learned from

outside speakers. A participant explained how she connected with speakers at the workshop and applied advice into her practice:

> *First, the advice that I sought from (speakers) this past summer was invaluable. The recommendation to be patient and build relationships with my community partner was just what I needed to build confidence and trust, and now we are fully underway. There are other recommendations I received from (speakers), and those will come into play later as the project continues to mature and develop. (CCC-MB)*

Discussion

Across all three programs, participants reported in the Likert scale questions that they strongly agreed or agreed that interaction with other participants and co-leaders/facilitators had impacted their practice change. Previous research has demonstrated the importance of networked learning among teachers (Lieberman, 2000) by applying a teacher social development framework (B. Bell & Gilbert, 1996) or community of practice (Wenger, 2000). The results of this study add to past research in professional development that focused on teachers' network structures (Kellogg et al., 2014), adaptation of teaching practice in classroom (Penuel et al., 2012), and teachers' intent to innovate at school (Moolenaar, Daly, Cornelissen, et al., 2014) by linking network structures and educator practice outcomes.

However, the results of the relationships between network measures and practice change varied across the three programs. The results showed a significant positive relationship between in-degree centrality and practice change in the PA SC and PLC. Participants with higher in-degree centrality occupied central positions in the network, perhaps granting them prestige to get access to resources (Knoke & Burt, 1983). On the contrary, participants who had low in-degree centrality occupied peripheral positions in the network and might find it difficult to seek resources. Although not examining the same outcomes, previous studies also found a positive relationship between degree centrality and students' academic performance (Jiang et al., 2014; Russo & Koesten, 2005). Russo and Koesten (2005) suggested that students felt their

contribution was validated when others communicated directly to them, which led to their motivation to learn more and better performance. The PA SC and PLC participants who received more connections from other participants might be motivated to engage in more professional development activities and change their practices.

The relationships of out-degree centrality and closeness to practice change were not significant in the PLC and CCC, whereas in the PA SC, before program out-degree and closeness were significantly related to practice change but after the program measures showed no significant results. The out-degree and closeness centrality before the program had significantly positive relationships with participants' practice change in the PA SC, indicating that the PA SC participants who sought information from others and had shorter distance to others before the program were more likely to change their practice. The result of a positive relationship between out-degree centrality and practice change was consistent with findings of previous studies on school teachers (Moolenaar, Daly, Cornelissen, et al., 2014; Penuel et al., 2012). Studies also suggested a positive relationship between closeness and students' academic performance, meaning that a learner with closer connections to other learners was more likely to achieve higher academic performance (Cho et al., 2007; Gašević et al., 2013; Joksimović et al., 2016).

The non-significant relationships of out-degree and closeness centrality to practice change can be explained by Nahapiet and Ghoshal (1998) who suggested that as interpersonal networks became dense, the strong norms and mutual identification might limit openness to new information. McFadyen and Cannella (2004) also found that the number of relationships had a positive and then a negative effect with increasing relationships on the knowledge creation, indicating the creating maintaining relationships had a cost. When participants seek more others for information and resources, they spent more time to develop access to needed resources and

maintain relationships.

Betweenness centrality was significantly associated with participants' practice change only in the PA SC. Those who occupied central positions in the networks were mostly on leadership team in the PA SC. They not only had interactions with other participants, but also connected to the EECapacity program providers and attended a national conference to expand connections beyond their own state consortium. Accessing more diverse information and resources than other participants may have motivated them to change their practices. Organizational studies research suggests that an individual in brokering position would have greater creativity and innovation (Burt, 2004; Fleming et al., 2007). In educational settings, Jiang et al. (2014) found betweenness had a significant positive association with students' academic performance. In contrast, Cho et al. (2007) who did not find significant relationship between betweenness centrality and students' academic performance argued that the impact of network positions differs between educational context and other contexts with greater competition. In a learning environment, network positions providing resource control (betweenness) would be less valuable than those positions providing participants with more (degree centrality) and quicker (closeness) access to numerous others. In the PLC and CCC, betweenness centrality was not significantly associated with educators' practice change. Unlike the PA SC, which had an internal leadership team, the PLC and CCC were facilitated by outside EECapacity leaders. Thus the PLC and CCC participants may have had more equal roles in their groups relative to the PA SC participants, and may have not felt obligated to occupy brokering positions to bridge other participants.

The results showed no significant relationship between network characteristics and practice change in the CCC. However, in the Likert scale survey questions, the participants

indicated that they changed their practice because of interacting with other participants. The possible explanation could be that the network got very dense after the program. Research suggests that a sparse network provides the benefits of access to new information and resources (Burt, 2001) while dense networks may produce redundant information flows (Coleman, 1988). Programs trying to achieve higher innovation performance need to develop a balanced mixture of both types of networks (Alguezaui & Filieri, 2010). Further, the CCC provided multiple ways for participants to gain information through both face-to-face and online activities, while the PA SC relied on face-to-face meetings and the PLC relied on online interactions. A mix of both types of activities provided the CCC participants intense interactions with each other and with facilitators and speakers. Thus, interacting with other participants was important but not the only way to gain information that could impact their practices.

The strength of ties before and after the program had a significant positive relationship with practice change in the PA SC, indicating that participants with stronger connections to each other were more likely to change practice. Previous studies also found a positive relationship between tie strength and innovation generation (K. G. Smith et al., 2005) and diffusion (McFadyen et al., 2009). But this relationship may diminish or reverse as the network gets stronger as in the CCC, due to increasingly redundant information (McFadyen & Cannella, 2004). Although Granovetter (1973) suggested that weak ties would be effective for information sharing and innovation, the adoption of the innovation requires strong ties to build trust (Moore & Westley, 2011). In the PLC and CCC, participants were from across the country and contacting each other might have relied on online interactions. In contrast, participants in the PA SC were closer geographically and may have visited each other in person and even created local collaborations. As a participant mentioned in the interview, she led a group of her audiences to

visit another participant's site. Thus, the type of contact participants had with each other may have differed among the groups, with a limited number of contacts having more influence on the PA SC participants. Because frequency of contact was used to determine strength of ties, strength of ties may have showed more impact in the PA SC practice relative to the other two groups.

Finally, the fact that most of the network measures were associated with practice change in the PA SC as opposed to one network measure in the PLC and no measures in the CCC might be due to different purposes of the three professional development programs. Both the PLC and CCC had more specific topics for participants and were project-based professional development programs. The PLC was designed for environmental educators who were interested in urban environmental education. Although participants had whole group interactions, the main focus was on collaborating in small groups to write eBook chapters, which largely impacted their network formation. In addition to the PLC participants, 2 facilitators and 16 other invited scholars and practitioners involved in writing, which provided external collaborations and interactions. These external interactions could provide information that may influence participants' practice change. Further, the CCC was designed for environmental educators to develop community climate change action projects. Participants sought information and advice for their projects not only from other participants, but also program facilitators and outside speakers. These facilitators played a key role in facilitating the participants' online interactions, and in motivating participants' learning and networking among each other (de Laat et al., 2007b; Y. Li et al., 2014). In contrast, the PA SC had neither specific topics nor group projects. Participants relied on interacting with each other to exchange information and resources. Thus

networks among participants had a more obvious relationship on their practice change than in the other two groups.

In addition to practice change, networking impacted other outcomes. For example, participants mentioned that they were inspired by exchanging ideas and practice with others, and were empowered by supporting each other, which reflects the personal development aspects of teacher development programs (B. Bell & Gilbert, 1996). Participants also indicated that their practice expanded to have a larger impact at the local, regional and even national level. These factors may eventually impact participants' practice.

At the group level, the change of practice indicated innovation to some extent. First, each group was a learning community, through which the participants built new networks and exchanged ideas (Chapter 2). The new networks formed may be considered as an innovation. Previous studies on grassroots innovation indicate that social innovation can develop at the community level through networking of activists and organizations (Seyfang & Haxeltine, 2012; Seyfang & Smith, 2007). In our study, one might argue that given the impact of networks, newly formed relationships and collaborations could be considered as a social innovation (de Moor, 2013; Mulgan et al., 2007; Murray, Caulier-Grice, & Mulgan, 2010). Further, the PLC eBook has been used by environmental educators in their practices, which suggests that it is an innovation at the group level, similar to a new product or patent developed by co-workers (Bund, Hubrich, Schmitz, Mildenberger, & Krley, 2013). Thus developing networks through professional development programs could foster innovation.

Limitations

The fact that some participants did not complete the social network surveys resulted in missing data in networks, which influenced the network measures. Also the practice change

values used in this study were from check box questions, in which the choices might overlap or not cover all possibilities. In addition, I conducted correlation analysis to examine the relationship between network characteristics and practice change. Therefore, the significant relationships do not indicate the causal influence of network centrality on educators' practice change. To examine how participants influence each other's practice in depth, future studies could use social influence models, which are designed to "estimate a teacher's implementation of certain teaching practices as a function of the prior behaviors of others around her (as a norm), and her own prior behaviors" (Frank et al., 2014, p. 122). Finally, the post-surveys and interviews were conducted right after the professional development programs and thus indicated short-term effects. Future studies should conduct longitudinal research to examine long-term effects of networks on educators' practice change.

Conclusion

This study provides a framework to examine educators' network and practice change in professional development in environmental education. The findings demonstrate that educators' networks influenced their practice, but the significance of relationships between specific network measures -- in-degree, out-degree, closeness and betweenness centrality and network tie strength -- and practice change varied among programs. The results suggest that researchers should take account of design of professional development activities including goals, interventions, and leadership when examining the impact of network structural elements on practice change.

This study opens up a way to explore relationships between network structures and educators' practice innovation in professional development programs. Practice innovation could be indicated by change of practice elements in environmental education at individual level. Through building networks in different groups, practice innovation could also be generated at the

group level. The results suggest future research connecting social network theory (Granovetter, 1973), practice theory (Reckwitz, 2002) and innovation theory (Young Foundation, 2006) to investigate the educators' interaction and practice innovation outcomes. For example, how do educators influence each other and change practice? What kinds of interactions lead to innovation? How do group dynamics impact group level innovation?

CHAPTER 5

CONCLUSION

Professional development programs create communities of practice for environmental educators to develop networks for exchanging ideas and resources, which may influence educators' practice. Through three chapters, this dissertation explored the role of networking in practice change in environmental education. Here I summarize the main findings from each chapter, reflect on theories and methods used in this research, discuss the threats to validity associated with this work, share the contributions of this dissertation, and conclude with recommendations for future professional development programs as well as for academic scholarship.

Main findings

Participants developed networks through professional development programs

Across all three programs, the professional networks became denser after the professional development activities (Chapter 2), indicating participants built more connections for exchanging ideas and practices in environmental education through these professional development programs. Among the three programs, the community climate change fellowship, which facilitated intense face-to-face interactions for participants, had the highest density and average degree centrality after the program activities.

Professional development activities influence the likelihood of tie formation

Participating in professional development activities including face-to-face and online interactions influenced the likelihood of forming network ties among participants (Chapter 2). The more face-to-face meetings and webinars a participant attended, the more likely the

participant was to connect to other participants in the PA SC. Also participants interacting with other participants and program facilitators through commenting on Facebook were more likely to connect to each other in the CCC. However, participants making more original posts on Facebook were less likely to connect to others in the PLC. Although these participants were active on Facebook, they did not appear to interact with others. Further, geographic distance did not have an impact on network formation, but closer distance might be crucial for developing stronger connections and collaborative projects.

Practice elements changed as a result of professional development programs

Participants incorporated new resources and ideas into their practices across all three programs (Chapter 3). However, changes in other practice elements varied across the three programs. The practice element goals only shifted in the PA SC, which may have been due to how the program integrated two groups of participants with different perspectives on working with youth, i.e., environmental educators and youth and community development professionals. Participants added more educational activities in the PLC and CCC, which had diverse participants across the country and involved project-based assignments. The practice elements age groups of audiences and settings changed only in the CCC, in which participants developed new projects to address climate change issues.

Network structure and tie strength were associated with practice change

Participants who received more connections from others were more likely to change their practices in the PA SC, with mostly face-to-face activities, and in the PLC with mostly online interactions (Chapter 4). Other network structural properties and tie strength were associated with practice only in the PA SC. Although the results from interviews and reports showed the importance of interacting with other participants to participants' practice change in the CCC,

other factors may also play a role in changing participants' practice such as materials shared by program providers and interacting with program facilitators and guest speakers.

Reflections

Below I reflect on theories and methods used in this study including communities of practice, social network analysis, practice elements, measuring practice change, innovation, and professional development.

Communities of practice

I used communities of practice theory as an overall framework for this study. Using different dimensions of communities of practice helped us understand the educators' learning communities in a broad way. However, because of the inconsistent definitions of communities of practice (Cox, 2005; L. C. Li et al., 2009) and flexible boundaries between different communities of practice (Fox, 2000), it is difficult to identify such communities and distinguish them from other kinds of communities. In this study, I assume that each of three professional development programs in this study created a community of practice for environmental educators based on three dimensions of communities of practice. Although this assumption seems to conflict with Wenger's (1998) earlier argument that a community of practice is an emerging process and cannot be purposefully created, it is more consistent with Wenger et al.'s (2002) subsequent view that communities of practice can be created within organizations. Further, communities of practice should be a dynamic group that accepts newcomers (Wenger, 1998). In my study, the PA SC members joined and dropped out during the professional development process, in the PLC some members dropped out, but the CCC was a fixed group within the intervention period due to its fellowship requirement. Thus each of the cases in my study was a community of practice in some ways, but also had features not consistent with communities of practice.

To address the challenges of measuring communities of practice (Wenger, 2010), I proposed to connect the framework to social network analysis and practice theory. In particular, I measured the first dimension of communities of practice, *mutual engagement,* from a social network perspective, and used practice theory to understand the second dimension *joint enterprise*. However the study did not address the third dimension -- *shared repertoire*. Although I identified shared repertoire in each professional development program in this study, such as the eBook coauthored by the PLC participants, I did not explore the process of developing this dimension. In addition, the study ignored the identity development process, which was considered as a key feature of communities of practice (Wenger, 1998).

Educators may participate in multiple communities of practice (Wenger, 1998). I examined communities of practice for educators who participated in the professional development programs. The educators may be part of other communities of practice, to which they may have brought what they learned from the communities that are the focus of this study. For example, each of the CCC participants created a local climate change action project that engaged community members, which may become their own communities of practice. I focused on educators' communities of practice created by EECapacity rather than examining these local communities of practice. Further, educators could be in multiple educators' communities of practice within this study. Three participants were in both the PA SC and the PLC, and some of the PLC participants joined other EECapacity programs. These participants might play a broker role between different communities, a possibility worth exploring.

Social network analysis in education

Social network analysis is a useful method to understand participants' interactions, but researchers need to pay attention to specific measurements and interpretations. Using descriptive

analysis and visualizing networks helps us understand how well participants connect to each other at both group and individual levels. But some network measures such as density, reciprocity and transitivity may not be comparable between groups due to size of the networks. In addition, conducting exponential random graph models (ERGMs) helps us understand why participants form ties among each other. Although ERGMs are considered as powerful tools for examining mechanisms of network formation (Robins et al., 2007) and have been widely used in many fields, they are difficult to apply due to complex computational process (Desmarais & Cranmer, 2012).

Network surveys are useful to collect network data. In this study, the surveys asked participants to report to whom they went for information, advice, support or help for their environmental education programs. This broad definition of connections may capture different types of information flow in the networks. In addition, the surveys asked participants to identify frequency of contact, which indicates tie strength. However, this question neither captures the duration of each contact nor the means of contact such as in-person meetings, emails, and Facebook. Future studies should ask more specific questions about the types, duration and means of connections among participants.

Finally, this study only examined networks among participants themselves. However, in the professional development programs, participants not only interacted with each other, but also with facilitators, outside speakers, and materials provided by the programs. Y. Li et al. (2014) found that interacting with course facilitators was associated with participants' interaction among each other, and interacting with course content was associated with participants' adaptation of ideas. Future studies should explore other types of interactions in professional development programs.

Practice elements

In this study, I proposed six applied elements -- goals, audiences, settings, educational activities, resources and ideas -- to define an environmental education practice. These elements have been separately discussed as characteristics of environmental education in previous studies (Ashmann & Franzen, 2015; Eames et al., 2008; Y. Li et al., 2014; Stern et al., 2013). Examining these specific elements enables researchers and practitioners to understand the practice in depth. To conduct environmental education practice, educators set goals to guide the direction of the practice, identify audiences with whom they work, choose settings to conduct practice, conduct activities to achieve the goals, use resources to assist the practice, and apply ideas to inform practice. These elements are important to describe or design an environmental education practice. However, they do not capture other characteristics of environmental education such as topics (Eames et al., 2008) and outcomes (Stern et al., 2013). In addition, this study did not address the interactions of the elements and the dynamic nature of these interactions.

Previous studies, which applied practice theory in different fields, used more conceptual elements such as competences and meanings to define a practice. For example, competences were discussed in consumer studies (Shove & Pantzar, 2005) and environmental stewardship (Krasny et al., 2015). The success of environmental education practice may also depend on educators' competences to engage audiences and conduct activities. Thus future research could include competences as a practice element and examine its impact on environmental education practice. In addition, studies discussed the meanings of practice, for example, why people use Nordic sticks in walking (Shove & Pantzar, 2005), why people are interested in energy savings, (Gram-Hanssen, 2010) and why people conduct civic ecology practice (Krasny et al., 2015). Meanings could also be important in understanding why educators conduct environmental

education practice and why audiences engage in such practice. For example, one educator may conduct environmental education programs to increase a communities' awareness of local mining pollution and look for ways to mitigate the problem. Such practices mean protecting the local environment and community for him. Studies on socio-ecological memories in environmental stewardship (Tidball, 2014) and sense of place in environmental education (Kudryavtsev, Krasny, & Stedman, 2012) also reflect meanings, which are worth exploring in future research.

Measuring practice change

Previous studies mostly relied on qualitative methods to understand practice emergence (Krasny et al., 2015; Shove & Pantzar, 2005) and practice change (Gram-Hanssen, 2010). This study used a mixed-methods approach to measure practice change including surveys, interviews and content analysis of reports. The surveys included check box questions and Likert scale questions and quantified specific elements of practice, which enabled us to capture which elements participants changed, the degree to which they changed these elements, and what program factors they thought influenced these changes. This quantitative method is particularly helpful to identify specific changes in practice and relate these changes to other factors such as networks, especially for individual practice with a relatively large sample size.

However, there are some drawbacks with quantitative methods. First, the choices for the check box questions for elements such as goals and activities may overlap with each other or not cover all possibilities. Participants who reported adding more choices for one element might not have changed practice more than those who reported fewer choices. In addition, changes of practice elements may not always be beneficial for the practice. Increasing elements or decreasing elements does not necessarily indicate positive or negative impact on practice. To

address these problems, open-ended survey questions (used only for resources in this study) or interviews could be used to ask questions related to each element. Second, compared to tangible elements such audiences, settings, and activities, intangible elements like ideas are hard to measure. In addition to how much participants have changed ideas, questions could be added to surveys or interviews about how participants have applied ideas into their practices. Third, some participants may not have control over elements such as audiences and settings. Measuring changes of these elements may be meaningless to understand their practice. Thus when examining participants' practice, attention should be paid to institution factors that may constrain change of practice elements. In order to get a comprehensive understanding of practice change, future studies could also consider conducting observation or participatory research.

Practice change and innovation

Unlike technical innovations that have tangible indicators such as patents or products, social innovations do not lend themselves to standard means of measurement. Because of this, researchers have linked practice theory with studies about social innovations (Pantzar & Shove, 2010; Seyfang & Haxeltine, 2012; Seyfang & Smith, 2007; Shove & Pantzar, 2005). New practices are not simply defined by the generation of new products, but could consist of integrating new elements to existing ones or new combinations of existing elements. I applied practice theory to explore environmental education practice by measuring different elements of practice change as a way to indicate innovation. Because these changes in practice could be considered as incremental innovation defined as stepwise improvements to existing ideas, products or processes (McKeown, 2008), this approach helps us understand individual level innovation in practice. But changing more choices of each element or more types of elements may not mean more innovations. For example, changing only one program goal could mean

more significant change to the practice than adding two types of activities. Studies should explore ways to weigh elements and consider the interaction or new combinations of elements.

This dissertation also explored group level innovation through developing networks and exchanging ideas. Seyfang and Haxeltine (2012) suggested that social innovation could develop at the community level through networking. In this study, each group was a learning community and the new-formed networks among participants in each group may be considered as an innovation. In addition, the participants in one group produced an eBook, which has been used by environmental educators in their practices and disseminated to educators globally. The eBook, similar to a new product (Young Foundation, 2006), may be considered as a radical innovation, which is defined as creation or adoption of new ideas, products or processes (McKeown, 2008).

Professional development outcomes

Studies measuring outcomes of professional development programs have focused on educators' outcomes such as knowledge, skills (Dyment et al., 2013), altitudes, behavior and literacy (Álvarez-García et al., 2015), and student achievements (Soine & Lumpe, 2014). In this dissertation, I applied social network analysis and practice theory to measure educators' network and practice change as a result of professional development programs, which reflect two aspects of teacher development: social and professional (B. Bell & Gilbert, 1996). The focus on educators' practice also reflects the fourth level of Guskey's (2000) professional development model: participant use of new knowledge and skills in their practice. My results help us understand how educators applied learned ideas in their practice. However this approach emphasizes networks and practice, which may ignore another aspect of teacher development -- personal development (B. Bell & Gilbert, 1996) and the importance of educators themselves. The variation of educators' characteristics such as demographics, knowledge, teaching and

experience may impact their adaptation of ideas and the way they conduct environmental education practice. Y. Li et al. (2014) found that less experienced environmental educators were more likely to adapt learned ideas from an online professional development course. In addition, this practice-focused approach may miss the impact of professional development programs on students or audiences. Desimone (2009) proposed a model to describe the relationships between professional development and teacher knowledge and beliefs, classroom practice, and student outcomes. A comprehensive study should incorporate these three components -- practice, educators and audiences -- to examine professional development outcomes.

Threats to validity

The groups examined in this study had relatively small numbers of participants. Although using a small sample size is not unusual in social network research, it is hard to generalize findings to broader settings. In addition, the relative low response rates in two of the programs resulted in missing data in networks, which influenced the network measures and the power of regression and correlation analysis. In addition, these connections and their impacts may not sustain over time, which could be addressed by conducting longitudinal studies. Finally, in the surveys about practice elements, four out of six elements were examined by check box questions and two were assessed using open-ended questions. The choices for the check box questions for each element may overlap with each other or not cover all possibilities. Participants who reported adding fewer types of activities might add more other activities that were not listed as choices for the question. In addition, together with Likert scale questions, these self-reported results might be participants' perceptions or expectations of change rather than actual change in their practice.

Contributions

This dissertation adds to the communities of practice framework by exploring two of its dimensions -- mutual engagement and joint enterprise -- from social network and practice theory perspectives. This dissertation is also the first study I am aware of that used network models to examine how environmental educators build networks through professional development activities. The results help us understand how and why participants build connections among each other through which they exchange ideas and practices. This study adds to the literature that applies social network analysis to examine professional networks in an environmental education context, and has implications for professional development providers seeking to better design programs that aim to facilitate social learning among diverse environmental educators and related professionals.

In addition, by bridging practice theory and environmental education characteristics, I identified a comprehensive list of elements including goals, audiences, settings, educational activities, resources and ideas to define environmental education practice. These specific practice elements enable researchers and practitioners to understand the practice in depth. The study provides a new approach to measure professional development outcomes and a new framework to define environmental education practice.

Finally this dissertation related environmental educators' professional networks to their practice change. The results revealing the importance of interacting with participants and facilitators for exchanging ideas and practices in professional development programs, open up a way to explore relationships between network structures and educators' practice innovations in environmental education.

Recommendations

For professional development programs

EECapacity programs studied in this dissertation, including a state consortium, an online learning community and a fellowship program, are recommended for future professional development projects that are designed for exchanging ideas to foster innovation in environmental education. Although having different goals, participants and interventions, each of the three programs showed increasing connections among participants and practice change to some extent. I propose some recommendations for future professional development programs to enhance environmental educations' interaction, learning and practice.

In order to increase the diversity of information sharing, professional development programs should bring together diverse environmental educators for exchanging ideas and practices. Educators learn from diverse perspectives, which may foster innovation in practice (Biggs et al., 2010). Although cross-country networks with a greater diversity may promote innovative ideas, local networks provide more opportunities for closer and stronger connections, which may lead to long-term partnerships and collaborations. However, local connections may become homogenous over time, which may limit diversity and lead to redundant information flows (Newman & Dale, 2007). Thus, program leaders should create opportunities for and balance both types of networks. For example, the PA SC co-leaders not only interacted with other participants in the state consortium but also with the EECapacity program leaders. Program leaders could also assign a few educators to both local and national groups. Those educators could play a broker role to bridging different groups to promote new information flows between groups.

Further, program leaders should develop strategic means to facilitate groups of different

size. A relatively small group may create more interactions among participants for exchanging ideas and practices, which leads to dense networks. But dense networks may produce redundant information flows (Coleman, 1988). A big group, which may have loose connections among participants, could also promote impacts on participants' practice with proper facilitation, for example, collaborative projects like writing the eBook. The PLC participants worked in small groups to write the eBook and ranked participating in writing eBook the highest among factors that influenced their practices.

To promote exchanging ideas and practices, professional development programs should create diverse platforms that enable face-to-face and online interactions. The face-to-face interactions are particularly important for participants to enhance understanding and information sharing among each other. In this study, the CCC participants ranked interacting with outside speakers at the face-to-face workshop relatively high as a factor influencing their practice change. Haythornthwaite (2001) also found a catalytic effect of a short face-to-face interaction session on social and emotional exchanges among students in an online learning course. The PA SC and PLC participants interacted with outside speakers through webinars, and they ranked both interacting with outside speakers and webinars low. The results suggest that one-time, face-to-face interaction may have a larger impact on participants' practice change than a one-time webinar. Future programs trying to use webinars may want to make them more interactive or have one speaker giving multiple webinars to increase the influence on participants.

Despite the limited influence of webinars in this study, online activities are important, and are critical for participants interacting remotely. The fact that interacting on Facebook among participants in the PLC and CCC was associated with tie formation among participants suggests that a Facebook group could be used as a useful tool to engage participants. However,

program leaders or facilitators should be aware of privacy issues on Facebook and make each group as a closed group unless it is designed specifically for the public. Further, the results showed that participants who posted more on Facebook might not be active in interacting with others and Facebook posts could be overwhelming and involve unrelated information. Thus, program leaders should facilitate Facebook interactions to ensure the types of interactions and posts that will reach program goals for exchanging ideas and practices. In this study, the CCC participants ranked interacting with program leaders relatively high as a factor influencing their practices. Y. Li et al. (2014) also found that interacting with facilitators was positively associated with participants' networking with each other in an online professional development course.

Finally, project-based assignments enable participants to apply learned ideas and activities into practice right away. In this study, participants in the PLC and CCC, both of which had project-based assignments, were more likely to add new activities to their practice. Thus the project-based approach, for example new program development and collaborative book writing, is recommended for future professional development programs.

For future research

Future studies of networks among environmental educators could examine different types of connections such as tangible resources and intangible support, by adding questions about what information flows through networks. Research could also ask specific questions about the means through which participants exchange ideas and practices, for example, in-person meetings, emails, calls, and Facebook. In addition to investigating network formation mechanisms, future research should use social influence models to examine how participants impact each other's practice in depth. Further, research could test the practice elements of environmental education proposed in this study in different contexts and explore other potential elements as discussed

above.

APPENDIX 1

NETWORK SURVEYS

Goal: To investigate how professional networks change over time among participants
Group: PA SC, PLC and CCC

Please think about the participants below that you go to for information, advice, support, or help for your environmental education or youth/community programs. Check how often you contact each participant before/since the PA SC/PLC/CCC
Answer this question for the year BEFORE/SINCE the PA SC/PLC/CCC started.

Individual name	How many times have you had contact with the participant over the past six months BEFORE/SINCE the PA SC/PLC/CCC started Frequency: 5: Daily 4: Several times a week 3: Several times a month 2: Several times a year 1: Once
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
…	
26	

APPENDIX 2

SEMI-STRUCTURED INTERVIEW GUIDE

Goal: To understand how participants' networks and practice change over time (for Chapter 2) and how climate change fellows develop innovative practice (for Chapter 3 and 4)
Groups: PA SC and PLC

1. Can you briefly describe where your work is and what you do?
2. Can you briefly describe your environmental education program? What are your program goals? Who are your audiences? Where do you conduct your program? What teaching strategies do you use?
3. Has your participation in professional development activities (workshops, webinars, Facebook group discussion etc.) allowed you to develop networks with other educators and instructors? In what way? How do you connect to them?
4. PLC: You worked with (participant) on the eBook chapter, where did you get the ideas from to write the chapter? Has writing the eBook chapter influenced your program? How?
5. Has your environmental education program changed as a result of participating in professional development activities (workshops, webinars, Facebook group discussion etc.)? In what way? If things have not changed, why?
    - Have your program goals changed? Why?
    - Have the audiences in your program changed?
    - Have the settings in your program changed?
    - Have the resources used in your program changed?
    - Have the strategies for your program changed?
6. Has your participation in professional development activities allowed you to develop new ideas for your program? How?

Do you consider your current program as an innovative practice? Why or why not? Is it new for your organization, in what ways is it new? Did you take ideas from others in the PA SC/PLC? Where did any new ideas come from?

APPENDIX 3

PRACTICE RETROSPECTIVE SURVEY

Goal: To examine practice change in environmental education before and after professional development activities
Group: PA SC

What is the goal(s) of your environmental education program?
(Check all that apply before PA SC and now)

Goals	Before PA SC	Now
Environmental knowledge and attitudes		
Pro-environmental behavior (recycling, activism, etc.)		
Mitigate environmental problems (pollution, air quality, climate change, etc.)		
Solve social problems (environmental injustice, jobs, crime, health, etc.)		
Urban agriculture (community gardening, rooftop gardening, etc.)		
Ecosystem stewardship (streamside restoration, tree planting, invasive species removal, etc.)		
Positive youth development		
Community development, including families, social capital and trust		
Foster sense of place or connection to nature		
Facilitate participation in urban planning		
Other, please write the goal		

Who are audiences in your environmental education program?
(Check all that apply before PA SC and now)

Age groups	Before PA SC	Now
<6 years		
6–12 years		
13–19 years		
20–39 years		
40–64 years		
64 years		

Race	Before PA SC	Now
African American/Black		
Asian/Pacific Islander		
Hispanic/Latino		
Native American/First Nations		
White (Non-Hispanic)		
Other		

Where do you conduct your environmental education programs?
(Check all that apply before PA SC and now)

Settings	**Before PA SC**	**Now**
School		
Public libraries		
Museums		
Zoos or aquariums		
Botanical gardens		
Urban parks and other green areas		
Community gardens, urban farms, or rooftop farms		
Green infrastructure (e.g., green roofs, bioswales, green walls)		
Nature centers or ecology centers		
Nature area (e.g., forests, rivers, remote areas, and state or national parks)		
Other		

What educational activities do you use in your environmental education program?
(Check all that apply before PA SC and now)

Educational activities	**Before PA SC**	**Now**
Lessons-indoors		
Lessons-outdoors		
Walking tours, or neighborhood explorations		
Creating or using media		
Using online technology (e.g. apps, social networking sites)		
Creating artwork		
Camping, or residential programs		
Hands-on science activities (e.g., bird count, tree identification, water testing, environmental monitoring)		
Environmental stewardship (e.g., tree planting, community gardening, urban farming, ecosystem restoration)		
Visits to environmental facilities (e.g., water treatment plants, recycling centers, green infrastructure)		
Recreation		
Other		

How have you changed your programs as a result of participation in the PA SC?

As a *result of participation* in the PA SC, I have	Not Applicable	Not at all	A little bit	Some	A lot	Totally
Revised or added new goals to my programs						
Involved different or more types of audiences in my programs (e.g. age groups, ethnicities, and professions etc.)						
Expanded my programs to new settings (e.g. classrooms, community gardens, parks)						
Revised or developed new pedagogical strategies or teaching methods for my programs						
Used new resources to inform my programs (e.g. curricula, lesson plans, videos, fact sheets)						
Used ideas and practices learned from other participants in the state consortium in my programs						

Other changes, please explain

How have the resources that you use for your programs changed as a result of participation in the PA SC?

How have the evaluations that you conduct on your programs changed as a result of participation in the PA SC activities?

How much do you agree with the following statements?

my environmental education programs <u>have changed as a result of</u>	Not Applicable	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
Interacting with others						
Interacting with other State Consortium participants						
Interacting with the State Consortium co-leaders						
Interacting with outside speaker						
Activities						
Participating in online Facebook group discussion						
Participating in the webinars						
Participating in the face-to-face meetings/workshop						

Any other ways in which PA SC influenced your programs?

If there is one thing that most influenced your change in practice, what was it?

Your name

APPENDIX 4

PRACTICE SURVEY IN THE BEGINNING OF THE PROGRAM

Goal: To examine participants' environmental education practice before the professional development activities
Group: PLC and CCC

About your environmental education program:

What is the goal of your environmental education program? (Check all that apply)

- o Environmental knowledge and attitudes
- o Pro-environmental behavior (recycling, activism, etc.)
- o Mitigate environmental problems (pollution, air quality, climate change, etc.)
- o Solve social problems (environmental injustice, jobs, crime, health, etc.)
- o Urban agriculture (community gardening, rooftop gardening, etc.)
- o Ecosystem stewardship (streamside restoration, tree planting, invasive species removal, etc.)
- o Positive youth development
- o Community development, including families, social capital and trust
- o Foster sense of place or connection to nature
- o Facilitate participation in urban planning
- o Other, please write the goal.

What local or global issues does your environmental education program address?

Who are audiences in your environmental education program? (Check all that apply)

Race

- o African American/Black
- o Asian/Pacific Islander
- o Hispanic/Latino
- o Native American/First Nations
- o White (Non-Hispanic)
- o Other

Does your program focus on a specific land or water resource (e.g., Bronx River, Faith Community Garden)?

- o Yes, please write in name of that resource.
- o No.

Briefly describe the educational activities you use in your environmental education program.

Briefly describe any evaluations that you have conducted on your environmental education program, if applicable.

APPENDIX 5

PRACTICE SURVEY AFTER THE PROGRAM

Goal: To examine practice change in environmental education after the professional development activities
Group: PLC and CCC

What local or global issues does your current environmental education program address?

What is the goal(s) of your current environmental education program?
(Check all that apply)

- o Environmental knowledge and attitudes
- o Pro-environmental behavior (recycling, activism, etc.)
- o Mitigate environmental problems (pollution, air quality, climate change, etc.)
- o Solve social problems (environmental injustice, jobs, crime, health, etc.)
- o Urban agriculture (community gardening, rooftop gardening, etc.)
- o Ecosystem stewardship (streamside restoration, tree planting, invasive species removal, etc.)
- o Positive youth development
- o Community development, including families, social capital and trust
- o Foster sense of place or connection to nature
- o Facilitate participation in urban planning
- o Other, please write the goal.

Who are audiences in your current environmental education program?
(Check all that apply)
Race

- o African American/Black
- o Asian/Pacific Islander
- o Hispanic/Latino
- o Native American/First Nations
- o White (Non-Hispanic)
- o Other

Who are audiences in your environmental education program?
(Check all that apply before PLC/CCC and now)

Age group	**Before PLC/CCC started**	**Now**
<6 years		
6–12 years		
13–19 years		
20–39 years		
40–64 years		
64 years		

Where do you conduct your environmental education programs?
(Check all that apply before PLC/CCC and now)

Settings	**Before PLC/CCC**	**Now**
School		
Public libraries		
Museums		
Zoos or aquariums		
Botanical gardens		
Urban parks and other green areas		
Community gardens, urban farms, or rooftop farms		
Green infrastructure (e.g., green roofs, bioswales, green walls)		
Nature centers or ecology centers		
Nature area (e.g., forests, rivers, remote areas, and state or national parks)		
Other		

What educational activities do you use in your environmental education program?
(Check all that apply before PLC and now)

Educational activities	**Before PLC/CCC**	**Now**
Lessons-indoors		
Lessons-outdoors		
Walking tours, or neighborhood explorations		
Creating or using media		
Using online technology (e.g. apps, social networking sites)		
Creating artwork		
Camping, or residential programs		
Hands-on science activities (e.g., bird count, tree identification, water testing, environmental monitoring)		
Environmental stewardship (e.g., tree planting, community gardening, urban farming, ecosystem restoration)		
Visits to environmental facilities (e.g., water treatment plants, recycling centers, green infrastructure)		
Recreation		
Environmental games/plays (only for PLC)		
Other		

How have you changed your programs as a result of participation in the PLC/CCC?

As a *result of participation* in the PLC/CCC, I have	Not Applicable	Not at all	A little bit	Some	A lot	Totally
Revised or added new goals to my programs						
Involved different or more types of audiences in my programs (e.g. age groups, ethnicities, and professions etc.)						
Expanded my programs to new settings (e.g. classrooms, community gardens, parks)						
Revised or developed new pedagogical strategies or teaching methods for my programs						
Used new resources to inform my programs (e.g. curricula, lesson plans, videos, fact sheets)						
Used ideas and practices learned from other participants in the PLC/CCC in my programs						

Other changes, please explain

How have the resources that you use for your programs changed as a result of participation in the PLC/CCC?

How have the evaluations that you conduct on your programs changed as a result of participation in the PLC/CCC?

How much do you agree with the following statements?

my environmental education programs have changed as a result of	Not Applicable	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
Interacting with others						
Interacting with other PLC/CCC participants						
Interacting with the instructors/program organizers						
Interacting with speakers of the webinars						
Interacting with speakers at the workshop (CCC)						
Interacting with speakers at the NAAEE conference (CCC)						
Activities						
Participating in online Facebook group discussion						
Participating in the webinars						
Participating in writing eBook chapters (CCC)						
Participating in the workshop (CCC)						
Participating in the NAAEE conference (CCC)						
Materials						
Materials provided by instructors						
Materials presented by speakers of the webinars						
Materials presented by speakers at the workshop (CCC)						
Materials presented by speakers at NAAEE conference (CCC)						
Materials shared by other PLC/CCC participants						
Accessing NAAEE Guidelines for Excellence						

Any other ways in which PLC/CCC influenced your programs?

If there is one thing that most influenced your change in practice, what was it?

Your name

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